DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

THE CLEANING AND RESTORATION OF MUSEUM EXHIBITS

THIRD REPORT UPON INVESTIGATIONS CONDUCTED AT THE BRITISH MUSEUM

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PREFACE

IT is now seven years since Dr. Alexander Scott, F.R.S., at the request of the Department of Scientific and Industrial Research, commenced his study of the cleaning, restoration, and preservation of museum exhibits. The purpose of his study was to investigate, from a scientific point of view, such processes as were known for the treatment of museum exhibits, and to discover new processes based upon exact scientific knowledge. It was hoped that, as a result of this study, it would be possible to place in the hands of curators, private collectors and others, methods for the cleaning, restoration, and preservation of objects of archæological or artistic value which could be recommended as "safe" and effective. Certain of Dr. Scott's results have already been described in the *First* and *Second Reports** upon investigations conducted at the British Museum, and since their publication further results have been obtained. In view of the prolonged experience of the utilisation and efficacy of the methods recommended in the above Reports, it appeared desirable to prepare a third Report dealing comprehensively with the whole of the processes examined or evolved from the outset of the work. Dr. Scott has accordingly prepared the following account of his work, which, read in conjunction with the two previous Reports, will provide a survey of the knowledge and experience gained to date at the British Museum Laboratory.

Evidence of the value of Dr. Scott's results has steadily accumulated. It is clear that the methods he has devised and tested are frequently and widely used and that, where they have been adopted, there has been a marked improvement in the condition of the exhibits

*A comprehensive list of the Department's publications may be obtained on application to the address overleaf.

treated and an arrest of their deterioration. It is becoming more generally realised that the only "safe" methods of cleaning, restoration, and preservation are those based on accurate scientific knowledge of the processes themselves and of the nature of the exhibits in question.

Attention should be drawn to the warning given in the two previous Reports. The methods and reagents described may be regarded as "safe" if used with ordinary care and discretion; and variation of the instructions given, or any application of the methods to objects not specifically referred to in the text, should be made only by skilled workers, and after careful prior experiment upon comparatively valueless objects.

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THE CLEANING AND RESTORATION OF MUSEUM EXHIBITS

INTRODUCTION

MANY of the processes described in the earlier Reports,* for the cleaning, restoration and preservation of museum exhibits, although based on scientific principles, were of a somewhat tentative nature in that time had not permitted a prolonged test of their efficiency. It has now been possible to give these processes prolonged trial, and their suitability has been confirmed while further experience has suggested certain modifications in detail which are outlined in the following pages.

The general scheme of operations in any restoration work must, first of all, be to determine, as far as possible, the various causes of deterioration, and, having done this, to find a safe means of arresting the processes of change and decay. By working on these lines it has been possible to arrive at processes which, after the lapse of five years, have shown no deleterious action of their own, and which, so far, seem to have been efficacious in preserving the great variety of objects which have been subjected to treatment. That there is yet room for many processes and methods of cleaning cannot be denied. A constant series of new problems is provided by the infinite range of museum exhibits, and these problems are often modified greatly by differences in constitution of the objects and the varying conditions to which these have been subjected in the past.

In the following pages are set forth various types of work with such details as may be thought of interest and usefulness to curators of museums and to the numerous

* *The Cleaning and Restoration of Museum Exhibits, 1st Report,* 1921, *2nd Report,* 1923. Published by H.M. Stationery Office. Price 2s. each, net.

private collectors. It is but seldom that the problems in their various conditions and complexities will again present themselves just as described here, and it is hoped that the details given may not only be of direct assistance to collectors, but may encourage them to feel that many valuable objects which seem irreparable on account of the condition into which they have fallen, are still worth endeavouring to preserve. Even if these endeavours should only be partially successful from the point of view of restoration, in almost every case details of manufacture will be revealed and light thrown upon the causes and mechanism of decay, and these facts alone may prove worthy of being recorded, if for no other reason than to warn others in charge of similar specimens and faced with like problems.

A number of notes has been added at the end of the Report in the hope that they may prove of general utility, especially to those who have no good laboratory facilities. Although there are many solutions, cements, varnishes, etc., which can readily be prepared by the amateur, it may often save much valuable time and also secure more uniform materials and treatment if certain preparations are purchased ready for use. Correspondence on the subjects dealt with in former Reports has indicated very clearly that many collectors have neither the laboratory facilities nor experience to prepare many necessary solutions and reagents, and would still find it difficult even if instructions were given in greater detail. On this account it was considered that reference might be made in the "Notes" to certain commercial products which have been tested in this laboratory and found efficient for the various purposes specified. Where reference is made to proprietary articles it should be understood that those mentioned are not necessarily the only ones suitable or available for the purpose; the articles mentioned are those which happen to have been

tested in the British Museum Laboratory and found satisfactory. It must be emphasized, however, that the use of any commercial product the composition of which is unknown is greatly to be deprecated. Where there is the least shadow of doubt it is well to determine by careful experiment the effect of a small portion in an odd corner of the specimen before proceeding with the actual restoration.

PRINTS AND PICTURES

IN the two former Reports from the British Museum Laboratory methods were outlined for the treatment of prints and pictures which have since been employed, in some cases with slight modifications, over a period of years. They have survived the test of time very favourably, and the experience gained in their application to a great variety of specimens makes it possible, at this stage, to furnish more detailed information, both as to the methods available, and to their selection in particular cases.

For cleaning and restoring discoloured and " foxed " prints the use of bleaching powder and dilute hydrochloric acid, when applied with the necessary caution, seems to be safest, and the method more generally useful where the pigments employed consist of lampblack and similar varieties of carbon (as in printer's ink).

Hydrogen peroxide vapour was also recommended for the clearing up of engravings, especially in cases where the presence of water was undesirable. This was generally applied by means of a dried stucco plate. It was found, however, that in certain cases this environment still contained enough moisture to wrinkle and distort the picture and its mount. Accordingly, recourse was had to an ethereal solution of hydrogen peroxide, easily prepared by shaking up the aqueous solution of hydrogen peroxide of commerce with about an equal volume of ordinary ether (so-called sulphuric ether). The ethereal layer floats on the top of the aqueous one and may be applied to the stains with a camel's hair brush, care being taken not to allow the brush to touch the aqueous layer. It may be noted incidentally that very pure hydrogen peroxide solution can now be obtained commercially,

declared to be "free from barium salts and from phosphoric acid." A third method of applying this reagent is in alcoholic solution, equal quantities of hydrogen peroxide solution and absolute alcohol being simply mixed and applied, as before, with a fine brush. The latter method is preferable in cases where gum or gelatine is used in the body colour of a painting. It renders the application of the liquid more uniform and minimises the danger of cockling the picture or mount.

The use of the ethereal solution of hydrogen peroxide is well exemplified in the treatment of a large number of colour prints by William Blake, which were cleared up brilliantly and rapidly by means of this reagent. After treatment many of these were exhibited in the Print Exhibition Room of the Museum, in King Edward VII's Galleries. The discolouration was largely due to the ordinary cause, namely, tarnishing of the flake white used, and in many cases this was accentuated by the poor quality of the gelatine or glue used by Blake. Examples of the effect of the ethereal solution are shown in Figs. 1 and 1A, 2 and 2A, 3 and 3A.

Alcoholic hydrogen peroxide was employed in the case of a very interesting and valuable set of water-colour drawings of Venice and the Venetian islands, about fifty pictures in all, by Giacomo Guardi (A.D. 1764–1835). These varied much in the extent of the blackening of the lead carbonate. That this was caused by the action of the air penetrating between the leaves of the album in which they had been mounted is shown clearly by Fig. 4, a photograph of the upper member of a pair mounted on one page of the album. One picture in process of restoration is shown in Fig. 4A, and a restored specimen in Fig. 4B. An illuminating example of the removal of mould spots by this treatment is shown in Figs. 5 and 5A.

For the removal of old and coloured oil and varnish, no reagent has been found to equal pyridine, a solvent

first recommended in the *First Report.* Although it removes the brown colouration in nearly every case, it is sometimes impossible to get rid entirely of all trace of stain, where oxidation and other changes in the oil have given rise to insoluble matter finely dispersed through the tissue. Good examples of the successful application of pyridine in this connection are exemplified in the illustrations, Figs. 6 and 6A. Fig. 6 shows an Arabic book on which oil had been spilt many years ago, and the stain had in time become dark brown. By careful application of the reagent with a glass brush the stain became rapidly lighter, the coloured solvent being removed with white blotting paper, which was replaced with fresh as required. The page was in this manner restored to its original whiteness so completely that no sign of stain could be detected in it afterwards. The negative of a photograph taken after cleaning also failed to reveal any evidence of the stain, although this is generally a more severe test than visual examination.

An oil-stained engraving, of no particular value except that the stains were known to be about a hundred years old, was made the subject of prolonged and drastic treatment by various reagents. The initial condition of the engraving seemed to indicate that it had been lying in a house-painter's workshop, as stains of green, red, deep cream colour and pure white were all present. The action of the pyridine in disintegrating the lumps of hard and dried paint was most pronounced, rendering them easily removable by a stiff brush or by the careful application of a needle. Figs. 7 and 7A show the engraving (dated 1767), before and after treatment. No reagents tried could weaken the stain seen at the bottom of the picture, which remained, even after prolonged bleaching. It was less easily wet when immersed in water than the other parts of the paper. Amongst the reagents tried were alcohol, carbon tetrachloride, trichlorethane, tri-

chlorethylene, acetone and ethyl acetate, as well as mixtures of some of these.

A frequent cause of disfiguration in old prints and pictures is that caused through the agency of mould. The stain may be due either to the actual presence of fungoid growth, which will necessitate sterilisation of the print, or the colour may have been elaborated sometime in the past by an organism which has since disappeared. In the latter case, one or other of the bleaching methods outlined above will generally suffice to remove the stain.

A method of sterilisation has now been devised, depending on the use of thymol, a reagent suggested in the *First Report* as giving promise of being a suitable medium. Thymol has been tested in various ways and seems to be extremely efficacious; it is easily applied and is safe because of its want of chemical reactivity. It may be applied in various ways, according to the nature of the object to be treated. Pictures, engravings, letters written in ordinary ink and similar objects are easily fumigated by placing them in trays in a fairly air-tight box, preferably above a large clock glass containing about a quarter of an ounce of thymol. An ordinary electric lamp fixed below the clock glass melts the thymol in a very short time after turning on, as its melting point is 44° Centigrade. The air within the box soon becomes highly impregnated with the vapour of the thymol which in the course of four or five hours seems to destroy the life of moulds and apparently of their spores also.

A simple experiment to test the efficiency of thymol was made with some Japanese paper which, when kept moist at the ordinary temperature for some days, always developed crimson and bright yellow spots of mould even when kept under glass. This seemed to indicate that the spores of these particular moulds were in the substance of the paper itself. A piece of this paper (*A*) was taken

and fumigated in the chamber as described above for three hours and was then placed between two pieces of glass, together with another unfumigated piece of the same paper (*B*), in such a manner that the specimens did not touch each other. A third piece (*C*) similar to (*B*) was mounted separately between glass, and all three pieces were moistened with distilled water and set aside (Fig. 8). In about a week (*C*) developed the spots as usual. After three months (despite the moisture that was maintained by regular wetting with distilled water), (*A*) and (*B*) were still immune, indicating that (*A*) had

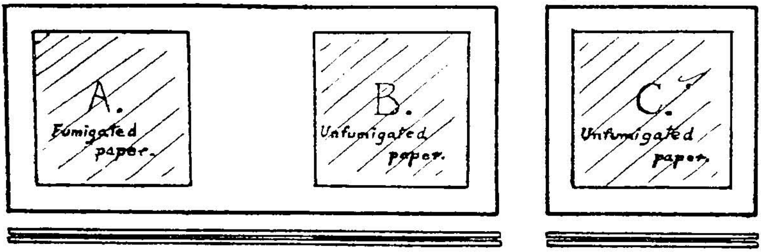

FIG. 8.

apparently retained enough thymol to sterilise (*B*). On removing the glass protecting (*A*) and (*B*) and simply touching them with (*C*), both (*A*) and (*B*) developed the coloured spots in the course of some weeks. It appears therefore, that any spores or mould in a dormant condition had been killed by the thymol vapour whilst between the plates, thus demonstrating its efficacy as a sterilising medium. At the same time, one must guard against exposing objects, even though sterilised, to the possible infection by mould spores, avoiding the conditions of dampness and darkness conducive to the growth of such organisms.

A picture of a type different from those cited hitherto, and of great historical interest, is that of Oliver Cromwell

(by Samuel Cooper), the property of Sidney Sussex College, Cambridge. On examination this was found to be suffering from various forms of decay which will be apparent from the following description. The portrait is executed in pastel on paper mounted on an oak panel measuring 15 by 12¾ inches. This panel is reinforced with oaken fillets at top and bottom and a rabbet has been let in, but despite these precautions to avert possible warping, cracks have started in the wood; these were probably caused, in part at least, by the screws employed. To prevent these cracks from developing more seriously, oaken dovetails of X-shape have at some later period been let into the back, and the whole roughly smoothed with a plane. This is clearly shown in the photograph of the back of the panel, Fig. 9. The picture, mounted *passe partout*, had a glass plate a very little larger than the oak panel bound to it by strips of paper. Apparently at no distant date the glass had been removed, probably to photograph the picture more satisfactorily. In fastening it together again, paste, which had not been sterilised, had been used, for it was noticed that at various points, mostly near the margin, mould spots were appearing; this was especially the case at the top. Further, the crack which had formed had been filled up with an oily putty which had the effect of rendering it only the more noticeable, owing to the oil diffusing into the paper and chalk, and both darkening and broadening the flaw. A certain amount of discolouration of the whites from the usual cause also required treatment.

Thus, treatment was required, (1) for moulds, (2) for discoloured white lead, (3) for oily putty, and (4) for rectification of the discrepancy of size in the glass and the panel, and to keep the glass from touching the pastel anywhere. The picture was therefore fumigated at a comparatively low temperature (40° Centigrade) with thymol vapour. After the fumigation it was found that

the remains of the mycelia and mould spots could be removed by gently lifting them off with a very small camel's hair brush. For the discoloured white lead, a solution of hydrogen peroxide in ether was employed most successfully. The oily putty had in the course of time shrunk in the cracks and was easily removed by means of an ordinary pin and the crack filled up with fine chalk powder coloured to match the various tints. To give the powder the necessary cohesion a dilute solution of cellulose acetate was used. To prevent the covering glass touching the pastel anywhere and at the same time to prevent the glass projecting over the panel thin fillets of wood were fastened to the edges maintaining the glass about a twentieth of an inch from the picture. The whole was then fumigated with thymol once more and bound up first with a strip of fine linen and this covered with another strip of thin tough paper, the flour paste employed in the binding having 1 per cent. of mercuric chloride (corrosive sublimate) added to prevent the growth of moulds or possible attack of insects. The portrait before and after treatment is shown in Figs. 9A and 9B.

Writings on materials other than paper and parchment have also been treated so as to render them more legible. One of the most interesting and at first sight impossible problems was to render again legible what had been written on wax, which had subsequently been partially melted by heat. Two wax tablets, mounted together in wood as a single page of a book, had been consulted on a dull day in the summer of 1924, and left for a short time near a window. On one of the rare occasions in that summer, the sun shone out strongly for a short time without warning, and its rays, falling on the blackened wax melted the surface defacing the writing, *see* Fig. 10A. By careful scraping with a razor blade, followed by gently rubbing with a small pad of cotton-wool moistened with petroleum ether, the tablets were brought back to the

condition shown in Fig. 10, when the greater part of the inscription could again be read. Apparently the wax surface had been blackened before being written upon, and the effect of the stylus used in writing had so hardened the incised lines that even on fusion of the mass they retained their form more or less accurately.

Of quite another type were rolls of thin lead foil some of which had incised writings on both sides, some only on one side. They had originally been enclosed in an outer casing of thin sheet copper of somewhat greater breadth than the lead sheets which latter measured about 12 inches in length by about one and a half in breadth. The lead strips had been tightly rolled up and then wrapped up in the thin sheet copper, the edges of the copper being bent over the ends of the leaden roll and one end filled up with clay and sealed. The copper covering was in all cases converted into a brittle mixture of copper oxides and carbonate, and the lead so encrusted that the writing was indecipherable except in isolated spots. No doubt the juxtaposition of the two metals hastened the corrosion, especially in the covering. By careful unrolling of the lead and washing with dilute acids, usually nitric or sulphuric, applied by means of a pad of cotton wool, the lead foil being extended on a glass plate, what remained of the writings was rendered legible once more (Figs. 11 and 11A).

Numbers of incised bronze and copper tablets have been treated and the corroded surface reduced once again to metal, making it possible for the writings to be translated, whereas, before treatment, the oxides and carbonates of copper had filled and so distorted the inscriptions as to make this quite impossible. These will be referred to later in the section dealing with bronzes.

For the benefit of artists and others who have to work with old drawing paper, reference may be made, in concluding this section, to a remedy, or at least a pallia-

tive, for certain troubles often associated with such paper. When old drawing paper is immersed in water it frequently shows spots which become transparent long before the rest of the paper has become thoroughly soaked. This is due to the destruction of the sizing of the paper, usually by bacterial agencies. Papers which have been taken to seaside places and other situations where the moisture in the atmosphere is high are peculiarly liable to this change, the clear spots having become a form of blotting-paper through the destruction of the size. When water-colours are applied to such paper these porous spots absorb an extra large amount of water, and the pigment contained in suspension is filtered out from the liquid, the result being that dark patches are formed wherever such porosity exists. To an artist who was in difficulties from this trouble the use of a solution of cellulose acetate in acetone was suggested, after various experiments had been made. This was simply brushed over the surface of the paper and allowed to dry. The best strength of solution for this purpose seemed to be from 2 to 2½ per cent. This he reported to have been a complete remedy for the trouble. Cellulose acetate is apt to dry with a whitish opalescent surface when the material to which it is applied is not perfectly dry. In this case with a white paper this is perhaps a slight advantage. No doubt the porosity of the paper is affected, but this treatment seems at least to render the surface once more uniform as far as water-colour drawings are concerned. It enabled the artist to complete numerous somewhat unfinished drawings which had been left in that condition for several years.

Drawing paper has been examined which bears the characteristic circular hole made by an *anobiid* beetle. Many reagents have been suggested to destroy this pest, one of the most effective of which is carbon disulphide; this liquid, however, possesses the disadvantage of being

extremely inflammable. Carbon tetrachloride, a somewhat less effective insecticide, is, on the other hand, non-inflammable. It was found that a non-inflammable mixture could be made consisting of 20 per cent. carbon disulphide in carbon tetrachloride, which thus combines the advantages of each and can be employed as an insecticide either in the case of paper or furniture.

STONE AND EARTHENWARE

IT need hardly be pointed out that the deterioration of stone objects in a museum is occasioned, not by the variety of disintegrating influences which may combine to attack the stone of buildings, but rather through certain of these influences acting in a more acute form because of the specimens having been buried in the earth generally for many years before discovery. The prime cause of decay is the crystallisation of salts within the stone or immediately beneath and on its surface.

The effect of impurities in the atmosphere, especially of our towns, where the combustion of raw coal produces substances such as sulphuric acid in large quantity, is that chemical reactions take place on our modern building stones which change the composition of the existing substances, converting, *e.g.*, carbonate of lime to gypsum, which in course of time crystallises and disintegrates the fabric of the stone. With museum exhibits, however, it is not so much this chemical change that we are concerned with as the fact that most specimens that have been excavated from the soil have their pores already full of salts. In many objects this is evidenced by a white crystalline efflorescence over the surface.

When water evaporates from a porous surface the residual solution must become more concentrated in dissolved matter. This increases the surface tension and therefore the force of capillary attraction, which operates to draw more salt solution towards the evaporating surface. Thus it is that the percentage of salt is high at no great depth in a porous soil, and stone or earthenware objects found in this environment, especially in warm countries, always contain much salt. After the object has been excavated the surface of evaporation

now becomes the surface of the object, and the same law operates to bring the crystals to this surface, though, under museum conditions, the moisture in the atmosphere is so small that it may be a very long time before the formation of a superficial crystalline efflorescence becomes apparent. Nevertheless, during this period crystals which are dissolving and growing within the stone are having a decidedly deleterious effect upon its structure. At first sight it may seem strange that objects of hard stone should change at all in the atmosphere of a museum, which is maintained so that changes in temperature and moisture are as small as possible. While changes in temperature alone have, in this country at least, but slight effects on stone objects, many suffer much from variations in moisture in conjunction with those of temperature.

Of the salts found in stone specimens, some remain quite dry even in a moist atmosphere, but there are others extremely soluble, which on a damp day abstract so much water from the atmosphere that they become liquid drops which soak into the interstices of the stone. On a dry day the atmosphere is ready to take up much water vapour and these moist portions of stone dry up, the salt crystallising in the body of the stone. Repeated analyses of the crystals efflorescing from stone specimens from all parts of the world show that the chief salts which crystallise out in these efflorescences are sodium chloride and sulphate along with potassium nitrate. Calcium and magnesium chlorides, nitrates and sulphates are also almost invariably present, but in small quantities only.

The usual method of removing these salts and so arresting decay caused by their presence, is to soak the specimens in water with repeated changes until, after one or two changes of distilled water this liquid is proved to contain no chloride; when this is the case on testing

a small portion of the liquid which has been acidified with pure nitric acid by the addition of silver nitrate solution, no white precipitate is obtained. The soaking is a very tedious process and is not too satisfactory, as on placing a dry stone in water the crystals near the surface are dissolved and this solution soaks further in as the water permeates the stone, and the salts are then only brought out again by the slow process of liquid diffusion. In order to obviate this objection a process has been worked out which brings the salts to the surface in an easily removable form without placing the exhibits in water at all; the efficiency of the process has been verified quantitatively.

When a drop of water is applied to the surface of a salt-charged stone the salts dissolve and the solution penetrates only as far as the quantity of water and the porosity of the stone will permit. As this drop dries it brings the salts gradually to the surface, in the manner already indicated, where they crystallise in due course; but the important feature is that, in the new procedure, instead of depending on the slow process of diffusion the agents utilised are evaporation and capillarity which allow of the action taking place much more quickly and with a high degree of efficiency.

In practice, water is not applied alone as most objects are too fragile to allow of the crystals being removed from their surfaces. It is possible, however, to obviate this by applying wet paper pulp (made by shaking up blotting paper with distilled water) to the surface of the specimen; occasionally the wet blotting paper may conveniently be spread in sheets forming a layer over the stone surface which soaks in enough water to dissolve the salts. Now when evaporation at the surface of the pulp begins the solution is drawn out of the stone and crystallisation sets in at the outside of the pulp layer instead of on the outside of the stone or earthenware, and when quite dry

the pulp comes off very easily bringing the salts with it. By repeating this procedure two or three times the salts are so much diminished in the outer layers that no further crystallisation need be feared in an ordinary museum atmosphere where the moisture and temperature are kept within limits.

The crystallisation of the salts naturally takes place most conspicuously where the porosity of the surface is greatest and this is usually at the same time the softest and most easily damaged part of the specimen. For the same reason soft porous stones suffer more than hard ones. When a stone, or even a hard air-dried clay has been primed with stucco or given a soft and porous layer of calcium carbonate as a ground work for painting or working into patterns, it is frequently found that this layer is warped or raised in blisters. This is constantly being illustrated in museum exhibits whether of stone or earthenware, glazed or unglazed. A very good example of how a porous limestone absorbs salts from the soil and, although apparently perfectly clean and unchangeable when first put into the museum case, gradually becomes almost unrecognisable through the influence of change of temperature and moisture upon the crystals within the stone, is shown in Fig. 12. This is a limestone foot so incrusted with long filamentous crystals that until these were removed it was impossible to tell whether it was a right or a left foot. Figs. 12A and 12B show it when cleaned and the crystals removed.

The small statuette in Fig. 13 was also of a porous limestone but in this case the detailed work was not on the limestone, but was on a coating of a slip of calcium carbonate of varying thickness. Before treatment the slip was being forced away from the stone in blisters of varying size due to the formation of crystals between the slip and the stone. The application of the wet blotting paper dissolved the crystals, and by absorbing the solu-

tion permitted the slip to be pushed back into its original place. After thorough treatment for the removal of the salts, the whole was dried and painted over with celluloid varnish so as to retain the displaced fragments in their places, and now the statuette may be handled with impunity.

The large water jar of porous earthenware seen in Fig. 14 shows the same effect of crystallisation of salts. In this case the salts came not from the soil, but from the water at one time stored in the vessel. The earthenware was porous throughout and the outer layer, which was of finer and smoother clay than the bulk of the jar, had scaled off almost completely in the lower parts. The use of such porous material for cooling the liquid contents, especially in hot climates with a dry atmosphere, is well known and extensively practised all over the world. The water soaks through to the outer surface and is there evaporated, abstracting much heat thereby from the jar and its contents. The continued passage of water from the inside to the outside naturally tends to the accumulation of the saline contents on the outside, followed by crystallisation and the gradual detachment of the outer layers. This jar, like so many others of similar type, was in an extremely friable condition, but by abstraction of the salts as above described, followed by thorough drying and subsequently by the application of weaker and then stronger solutions of celluloid, the whole has been so consolidated that it can be readily handled, and even rubbed with a cloth, without any particles becoming detached thereby. At the upper part the coarser earthenware had crumbled away so much as to leave a gap of about a twentieth of an inch between the outer crust and the jar.

A somewhat similar case in point of cure, but where the cause was entirely different, is that of a large Italian drug pot (Figs. 15 and 15A), in which the bluish-white

glaze was cracking off from the reddish ware below. This was probably due to the fact that the temperature of the fusion of the glaze had not been high enough to secure complete adhesion of the glaze to the body. Hence there was no question of any salts in the ware and the application of celluloid solution was sufficient to prevent further loss of the glazed layer.

An exceedingly interesting case which exhibited many new points for investigation, and which also raised many others which have not been completely solved, is that of a drug pot of Lambeth ware. The earthenware body of this specimen was almost white and the glaze bluish in tint with deep blue lettering. The glaze had been chipped off almost all round the base and in various parts there were flaws in the glazing no larger than pin-holes, but round these black spots blisters appeared, varying in size up to about an inch in diameter. As was expected these proved on examination to be due to the formation of crystals beneath, and the only remedy in this case seemed to be to extract the salts by soaking in water. Distilled water was used throughout in this case and it was changed once a week for over three months, the washings in each case being boiled to dryness and the residual crystalline deposits dried and preserved. In the end it was found that the united weight of saline matter amounted to no less than 29 grammes. The salts were almost entirely sodium sulphate and chloride with a notable quantity of calcium sulphate. There seemed to be no oily or other organic matter present to any marked extent, nor could zinc be detected, although the jar was made for and presumably contained "zinc ointment" when in use. Apparently, what had happened was that the jar with its chipped base had stood in some saline solution, and this had permeated the mass by capillarity. Evaporation, followed by crystallisation of the salts occurred at each minute hole in the glaze, and this

accounted for the blisters round each black spot. Figs. 16, 16A and 16B illustrate these various points.

There are other cases in which immersion in water and slow diffusion seem to be the only way by which the salts can be removed. A large number of tablets of baked clay covered with cuneiform inscriptions were found to be crumbling owing to their salt content. The surface could not be touched without removing or displacing the fine markings which had been pushed up from the body of the tablet by the crystal formation below. It was, therefore, impossible to adopt the usual practice of wrapping them in fine muslin and then placing them in water. The problem of removing the salts without disturbing the finest markings was solved by giving the tablets three coats of celluloid varnish, allowing each coat to dry before applying the next and then immersing the completely coated tablets in distilled water and continuing the washing as above described. When washed free from salts the tablets were dried and given a final coat of the same varnish. The skin of celluloid over the surface of the tablet allows diffusion of crystalloids to take place readily through it. A strong white precipitate of silver chloride was usually given within a quarter of an hour's soaking of the tablet. Cellulose acetate solutions were also tried, but the films were found to be so much weaker that they did not fix the crumbled surface nearly so well as the celluloid solution than which no better medium seemed possible.

Another point with regard to the glaze on earthenware was raised in connection with the vase (mei p'ing) with imperial dragons (1488–1505), shown in Fig. 17. The glaze is seen to be discoloured, especially in the lower parts, where it is thick. It was found that this brown colour was not attacked by acids such as hydrochloric acid, and not even by hydrofluoric acid. As the upper part was absolutely free from discolouration it was evident

that this was not due to any deposition of furnace dust nor could it be because of reduction due to furnace gases. Examination under the microscope showed the cause to be incomplete fusion and incorporation of the material used for the glaze. On the shoulder and wherever the glaze was pure white it seemed to consist of brilliant colourless spheres, and it is to this that the peculiar charm of such glaze is due. Wherever the discolouration was apparent, as in the thicker parts, the brilliant spheres were mixed with others which varied in tint from dark brown to the palest straw colour. Apparently, complete fusion and incorporation of the materials of the glaze only took place where it was sufficiently thin, as on the shoulder and the edges of the lip.

SILVER

WITH regard to the treatment of silver objects, there is but little to add to the simple methods already described in the two earlier Reports. As is well known, silver is a very soft metal, and on this account not well adapted to the wear and tear of daily use. This softness is overcome to a large extent for coinage and other purposes by alloying it with other metals, of which copper is most usual. The amount added varies enormously; for example, British standard silver contains only 7½ per cent. of copper, whilst some silver coins of the Emperor Probus were found to contain only 4½ per cent. of that metal. The method by which these latter were coated with a thin film of silver, so as to counterfeit a coin of high silver content has not been satisfactorily made out.

When alloys of silver with copper are buried in salt-containing soils or under other conditions which favour corrosion, the result, as long as any unchanged alloy remains, is that the alloy becomes coated more or less thickly with compounds of copper interspersed with metallic silver, either as isolated crystals or in the more or less continuous form of a sponge. In many instances this green coating has led to objects composed of alloys with a high silver content being actually catalogued as bronze. Also, many objects covered with green incrustations and likewise catalogued as bronze have been found to be so in fact, but sometimes skilful, artistic, inlaid silver ornament has come to light on cleaning which was quite hidden before.

A large number of articles of silver from recent excavations at Colchester were found to have been converted almost entirely into silver chloride and to be,

in consequence, very brittle. By treatment with caustic soda and zinc these were slowly reduced once more to the metal, naturally now in a spongy condition. After thoroughly washing out all the soda, these were dried, then raised to a low red heat. The fine silver sponge left after the reduction was thus consolidated and toughened, owing to the peculiar property which spongy precipitated silver has of drawing together when so heated. This strongly heated silver has a soft grey colour and is coherent enough to be burnished and rendered brilliant once more. The objects referred to above seemed to be part of a necklace or tiara made up of individual pieces resembling trefoil leaves.

One important item in the Colchester collection was apparently of the nature of a brooch with the head of Augustus (Figs. 18 and 18A). This was at first conjectured to have been made from a coin, but a more complete examination after restoration indicated that it had been independently fashioned as an ornament.

Another interesting example of the reduction of the incrustation of silver chloride was that of a pair of silver scales (Fig. 19) in which the contact of brass pins used in mounting the specimens gave rise to drops of green copper-chloride solution and the gradual growth of pure white silver crystals radiating from the points of contact of the pins with the silver chloride.

The use of formic acid in various strengths, both warm and cold, for cleaning all kinds of silver alloys, especially those with copper, has continued to give excellent results. As was pointed out in the *First Report*, the ready decomposition of silver formate into carbonic acid and metallic silver renders the use of this cleaning agent perfectly safe in that no corrosive action on the silver need be feared, the surface being left in a condition as nearly as is now possible to that which it presented originally. The action of this acid is practi-

cally confined to the solution and removal of the carbonates and oxides of such metals as lead and copper, the mechanism of the reaction being conversion into formates soluble in excess of the acid. It is frequently quite sufficient to wash over the surface, leaving the acid on for a short time only, and then to rub off the sulphide and other compounds insoluble in the acid, and to finish by washing thoroughly with pure water. A soft pad of cotton-wool, or in many cases merely the fingers are the best rubbers for fairly flat surfaces; a brush may be necessary where there is embossed or engraved work.

A good illustration of the cleansing action of formic acid is shown in Figs. 20, 20A, and 20B. No other reagent than dilute formic acid (5 per cent.) was applied, as described above.

The dark brown or black discolouration is usually due to the formation of silver sulphide or of silver subchloride, the latter being formed by the decomposition of the normal chloride of silver by the action of light and organic matter, and these two silver compounds are the insoluble substances which are loosened and then removed by gentle friction.

IRON OBJECTS

THE museum specimens which consist of iron or of iron along with other metals exhibit a great variety of problems, both in the states of decay in which they come for treatment and in the treatment required to arrest further change. No objects deteriorate so rapidly as these, and the reasons for this have already been given. Those of iron, either wrought, cast or in the form of steel, corrode rapidly in a moist atmosphere when salts are present in the coating of oxide with which they are almost invariably encased. When more electro-negative metals such as copper, silver and gold are present, however, this rate of decay is so much increased that it is comparatively rare to find any metallic iron remaining when one of these non-ferrous metals is, or has been in metallic contact with the iron. Too often the specimen is only a mass of iron oxide resulting from the change, and only the general form of the mass gives any clue to the purpose for which the iron object was originally made.

If, however, a comparatively thin coating of oxide and a large proportion of coherent metal should remain, a method of treatment which is extremely successful, as far as appearance goes, is to boil the article with a solution of stannous chloride kept faintly acid with hydrochloric acid. Small quantities of hydrochloric acid must be added from time to time as the iron oxide dissolves and neutralises it. The stannous chloride prevents, to a large extent, the attack of the metallic iron ; the free acid attacks the ferric oxide producing ferric chloride which is reduced at once to ferrous chloride ; the latter does not attack the metal as ferric chloride does. The possible objection is that this treatment may,

and usually does, give a coating of metallic tin to the iron rendering it a shade whiter than the pure iron. When *thoroughly* cleaned, the thin layer of tin should protect the underlying iron. To ensure this it is well, after the treatment with stannous chloride, to wash very thoroughly with distilled water followed by a hot bath of dilute caustic soda solution in which are pieces of granulated tin, again to wash well with pure water, and then varnish with thin dammar varnish or " duroprene " after thorough drying.

For the treatment of greatly corroded iron objects having a thick incrustation of oxide containing the salts from the soil in which the objects have been buried, the best scheme so far devised is to boil the objects with a dilute solution of caustic soda (about 5 per cent.) along with granulated zinc. The caustic soda decomposes the chlorides and oxy-chlorides of iron, while the zinc promotes electrolytically the passage of the chlorine from the iron into the liquid and towards the zinc. This holds good as long as any metallic iron remains. If all metallic iron has disappeared and only oxides and other compounds of iron remain, the problem resolves itself into how to make the specimens less friable and more easily handled without falling to pieces.

The manner in which iron objects fall to pieces when left to themselves is well shown in Figs. 21 and 22 and how they may be restored and treated so that no further change need be feared may be seen in Figs. 21A and 22A.

One cause of the very bad condition into which many museum exhibits of iron have fallen is the adoption, in the past, of a method often recommended for preserving iron. In this method the object is first heated so as to dry it thoroughly, and it is then immersed in a bath of hot paraffin wax. No doubt when intelligently applied this method has given good results, and the specimens seem to have remained unchanged for many years. But unless

all salts are previously removed, especially common salt, as has been already pointed out in the *First Report*, p. 10, there must always remain the danger, if not the certainty, of deterioration taking place and becoming apparent at some future date.

A better example to illustrate this could hardly be found than that of a collection of Merovingian buckles and other ornaments decorated with silver damascened work (Figs. 23 and 23A). When viewed by looking down upon them the silver pattern was fairly well seen, although almost the whole surface was lifted up irregularly. However, when viewed sideways (Fig. 23B), or in profile, the nature of the destruction became apparent at once. These specimens had been treated less than twenty years ago and no doubt looked fairly well for four or five years thereafter, but they gradually got into the lamentable condition in which they were brought for re-treatment.

The first thing to be done was to extract as completely as possible all the paraffin wax with hot benzol. After the paraffin had been removed and the objects dried, the salts were extracted with water along with some caustic soda to decompose any chlorine compounds of iron which had been formed. By careful washing followed by the application of a solution of potassium binoxalate (salts of sorrel) to dissolve some of the iron oxide, it became possible to push back the thin silver work into its place and thus restore to a large extent the original appearance of the objects. Of course all traces of the reagents used had to be carefully washed out in repeated changes of distilled water until nothing more could be extracted. The objects were then dried thoroughly in an air-bath and, when cold, coated with dammar varnish, partly to prevent the absorption of moisture but mainly to fasten down the fine silver work.

Similarly, by the use of potassium binoxalate a large portion of the Gowland collection (Figs. 24 and 24A) of

objects dating from about 900 A.D. were cleaned, and some degree of their original beauty restored to them. These specimens consisted largely of horse trappings which were made of iron. The iron had then been coated with copper (probably by immersion in a solution of some copper salt), and the copper in turn had been gilt by the application of thin gold leaf. This gold was practically hidden by the rust which had formed, and the whole collection looked as if it consisted of nothing but shaped pieces of iron oxide. All the objects had become very brittle and frail as they were so thin, and no metallic iron remained in any of them. By patient soaking in the binoxalate solution, which in aggravated cases had to be used warm, the comparatively thin coating of iron rust over the gold was dissolved off and the gilding revealed. The general scheme of the artistic work was thus brought out, and showed that silver also had been employed to a considerable extent. As was mentioned above, many of these objects were very frail and broken and thus had to be pieced together and strengthened by a backing of some kind. For this purpose the material sold as "Pyruma putty" proved most useful and very satisfactory, especially when, after drying in the air, it was dried still further in a steam oven at about 100° Centigrade. Under this treatment it becomes very hard and has now stood two years without deterioration. Instead of this substance, kaolin made up into a paste with silicate of sodium or potassium has been used with equal success when the dark colour of the "Pyruma" has been objectionable. The use of *potassium* silicate solution diminishes the risk of "white bloom" or efflorescence which sometimes occurs.

Owing to the great increase in volume which occurs when iron changes into its hydrated oxide, or common rust, the original form and structure of an iron object may be completely obliterated, especially if the workman-

ship be fine and the objects small. These masses, often shapeless, may, by suitable reagents, be so dissected as to show what they were originally.

For example, some almost shapeless masses of rust were among the objects resulting from Roman remains excavated at Colchester, which consisted of articles of iron, bronze and silver. These masses of rust were proved to be the remains of a coat of iron chain armour, by giving them first gentle treatment with dilute acid so as to free them from calcareous deposits, and following this by immersing them in caustic soda fused in a silver dish. This yielded many portions of iron oxide in the form of rings, and so it was possible to prove, not only what this mass had been, but to tell the exact size of the iron rings out of which the chain armour had been constructed.

One object of great historical interest which has been treated with a view to arresting corrosion by rusting is the helmet of the Black Prince (Fig. 25), which hangs above his tomb in Canterbury Cathedral. This had become very rusty, but, as it had never been buried in soil and so remained free from salts, it had not deteriorated to any alarming extent, nor had it been exposed to the fumes of burnt coal gas and the consequent corrosion by sulphuric acid. It was severely pitted all over, however, and having now been attended to it is hoped that it has been saved from further decay. The first step of the treatment was to remove the rust completely by means of a soft *iron* wire brush (not brass) ; the iron was then coated with " duroprene " to which sufficient lamp-black had been added to take away the unpleasant rusty-brown tint.

The helmet was surmounted by the " cap of maintenance " (Fig. 26), and this, again, by the crest in the form of a lion. The cap was in grey leather and had been painted in red and gold. Most of this decoration had disappeared, but during the cleaning a rose in gold could

be distinctly seen on a field of red. The lion was likewise of leather (cuir bouilli), which had been moulded to the required shape when soft and wet. The lower jaw was missing and the tail broken in one or two places. After the modelling the lion had been covered with a "gesso" of whiting and glue fashioned so as to represent the mane, &c., which was finally covered with gold leaf. When received this was almost everywhere hidden by the dust and grime of ages, which were retained somewhat tenaciously as the whole figure seemed to have been given at one time a coating or varnish of gelatine. By washing with water just warm enough to dissolve the gelatine, and applying the gentle friction of a soft camel's hair brush, the adherent dirt was removed without injury to what remained of the gilding. The "gesso" and gilding seemed to have been applied in diamond-shaped pieces, very many of which had been lost. The helmet, from its simple form, was at first thought to have been made and used for the funeral obsequies, but examination of the inside showed the remains of a leathern cushion, which seemed to indicate that it had been made for actual wear, and in all probability it was a tilting helmet or heaume. Its weight was 12 lb.

Two other helmets were treated in much the same way and deserve mention here as they present some additional points of interest to collectors and curators of museums. They, also, were much corroded by rust, and cleaning showed that they had both been ornamented, one with gold (Fig. 27), and the other, simpler one with silver (Figs. 28 and 28A). Unfortunately, the rusting had proceeded so far that no trace of any pattern beyond the mere gilding could be made out, but on that ornamented with silver a certain amount of the design was rendered apparent. These helmets are in the church of Whitelackington near Ilminster and are hung over the tomb of the Speke family there.

An interesting problem emanating from Lincoln Cathedral was presented in determining the best treatment to be applied to the 13th century iron railings and gates in the chancel. Like the Black Prince's helmet, these gates had never been buried and so were free from saline impurities. They had been painted and the central links had also been gilt. More detailed examination showed that they had been painted twice, probably at different dates, and the gilding probably done at a later period. One of the coats of paint had an iron oxide basis and the other was of a bluish grey colour and contained much lead. The remains of the gilding were so small in amount, and of no artistic interest, that it was considered that they were not worth preserving. The treatment recommended, after many experiments had been made with the small panel shown in Fig. 29, was to boil with caustic soda solution, wash, and dry at a high temperature, then remove all adherent rust with a soft iron wire brush and then paint with the same blue grey tint, and regild the links serving as bosses which held the component parts together.

LEAD

THE methods already described for the cleaning and preservation of leaden objects have been in constant use and require but little amendment as the result of five years experience. Careful application of dilute acids by means of a brush is usually all that is required, and in most cases it does not matter much whether acetic, nitric or sulphuric acid be used to dissolve off or to decompose the lead carbonate forming the incrustation. If acetic acid be used the subsequent washing must be very thorough, and in every case it is well to begin the washing with an alkali either with or without some lead oxide (litharge) dissolved in it.

The problem often arises whether a thin coating of carbonate ought to be removed or not. As has been indicated in former Reports, there is a very great increase in volume when metallic lead becomes converted into the usual basic lead carbonate. If this corrosion has not gone too far for removal the coating of carbonate may almost enhance the clearness of the original detail ; if the action be stopped at this stage this procedure is safer than cleaning off the coating, because under the latter the metal is almost invariably pitted all over. This tends to obscure any fine detail which was on the original metallic surface, although the detail may be still clearly made out on the surface of the coating of carbonate. These facts are well exemplified in Figs. 30 and 30A, which show how the detail survives even after prolonged corrosion. As this coating on the leaden medal was falling off and crumbling with the slightest touch, steps had to be taken to arrest further change. It was decided to retain the coating and to strengthen the incrustation so that the medal could be handled with safety. It was therefore

very carefully dried at 100° Centigrade in a steam-oven and then placed under the receiver of an air-pump arranged so that the medal could be flooded with gum dammar dissolved in benzol, whilst still in the vacuum. Air was then admitted and the medal removed from the solution, drained on blotting paper and then allowed to dry. Treated thus the surface showed no apparent change and no varnish-like glaze. After thorough drying it was so much strengthened that the specimen could be manipulated without danger, and casts were taken as a record of its present appearance.

The following Figs. 31 and 31A show a seal of Pope Paul III before and after thorough cleaning. They show clearly how the increase in volume of the incrustation rounds off the figures and causes loss in detail, and further how restoration of much detail is possible even though the metal be pitted considerably under the incrustation.

The restoration of writing on strips of metal has already been exemplified in the section on Prints and Drawings. In further illustration of such, the 11th century leaden mortuary cross (Figs. 32 and 32A) may be cited. The inscriptions recorded on the modern wooden backing were quite illegible on the cross, and accordingly recourse had to be had to the acid treatment as a means of recovering these. The cleaned cross shown in the accompanying figure has finally been thoroughly washed in caustic alkali and in distilled water, followed by drying and coating with dammar varnish.

It may be objected that such treatment causes leaden objects to lose much of their charm. In certain cases the justice of this criticism cannot be disputed, although this will depend largely on the nature of the object. In cases where the acid treatment is necessary to bring out detail it is desirable to clean the lead entirely, wash, dry,

and coat it with dammar varnish. Thereafter there can be no harm in attempting to recover some of the original "complexion" by the judicious use of a perfectly neutral medium such as pure dry kaolin, in imitation of the carbonate commonly associated with leaden objects of antiquity.

COPPER AND BRONZE

As regards their preservation and renovation, museum objects of copper and its various alloys present a vast and complicated field of study. Almost invariably articles of copper contain traces of foreign metals as impurity, notably silver, lead and arsenic, while copper alloys are employed in an infinite variety as regards their composition and constitution; these factors modify profoundly the power of the metal or alloy to withstand corrosion. In addition to this very variable factor of the metal basis itself, there are superadded all kinds of circumstances which tend to promote corrosion, such as burial in soils containing abundance of limestone and salts, or, as a contrast, in soils which possess a more or less pronounced acid reaction. Whatever may have been the condition, in times long past, of the object or its environment, there is no doubt that the action of moisture, which is usually present in some degree, and that of air and carbonic acid would all play an active part in determining its present condition. These influences would be greatest in the case of burial in a porous soil, or where a large surface of the object was exposed, and in an especial degree where the metal itself is notably porous.

It is found in practice that copper objects withstand these agencies better than any of the copper alloys, such as bronze and brass. In time, however, all become coated with a layer of copper compounds, and this layer contains the oxides of the other metals which were present in the original alloys. This coating, when fine, continuous and hard, has received the name of "patina." When slowly and uniformly formed and of a hard crystalline nature, it may take a high polish and by its beauty add much to

the artistic value of an object which, originally of bronze, was then appreciated because of the beauty of its form and its metallic lustre. This patina is too often of a more porous and of a softer nature than that so much sought after, and from its porosity tends to retain some of the saline constituents of the soil which have led to its formation. This retention of the salts, together with the moisture in the atmosphere, is revealed by the appearance of bright green spots, which may be either dry and powdery, or moist and pasty, according to the nature and quantity of the retained salts and the dryness of the atmosphere at the time of examination. Such are the symptoms of the so-called "bronze disease," about which there is nothing mysterious. The remedy is obvious, although in many cases by no means easy to apply, and consists in the removal of the soluble salts from the incrustation (together with certain other undesirable insoluble compounds). Prolonged soaking in water is not enough, for this will only remove the soluble salts, such as those of sodium, potassium, ammonium, and calcium. Some of these have given up part of their chlorine to form insoluble oxy-chlorides of copper and similar compounds. The latter may be decomposed by a large excess of water acting on them for a long time, but it is unsafe to trust to this. It is necessary that these compounds be decomposed by some reagent which will not attack either the patina which is good or the metal. The safest reagent for this purpose seems to be a strong solution of sodium sesquicarbonate, which can be used either cold, or, in aggravated cases, hot. The specimens are left in this solution as long as chlorine is being removed from the incrustation (test occasionally with silver nitrate, as directed in the section on Stone and Earthenware). This solution also acts very beneficially in loosening the incrustation of earth, sand, and clay which is a common accompaniment of objects which

have been dug up. The removal of these in this way is infinitely safer than the usual mechanical method or the equally drastic measure of treatment with dilute acids.

The group of vases and figures shown in the illustrations (Figs. 33 and 33A, 34 and 34A) demonstrate the result of applying this simple treatment.

When objects have been coated or plated with another metal this treatment with sodium sesquicarbonate is of special value. This is very well seen in the exquisite small gilt cup of Korean workmanship (Figs. 35 and 35A), which was so thickly coated with a green crust that the whole of the artistic work was obscured and no gilding was visible. Treatment with any reagent which would have dissolved the incrustation would almost certainly have removed some of the cuprous oxide underlying the gold which was so thin that it would have floated off and been lost.

For the reduction of the compounds of copper and their conversion into spongy metal in a form easily removed, warming with a solution of caustic soda together with metallic zinc has been much employed. This is, of course, nothing other than a simple form of electrolytic reduction. As the zinc can be employed in various forms, it gives more latitude and greater adaptability to each especial case than the direct application of the electric current from a battery or from the ordinary supply mains. The latter was tried, perhaps not very thoroughly, when this work was begun, but it was abandoned eventually for the treatment above outlined. There is no doubt that what may be called the " direct current method " can give excellent results, as shown by Professor Fink and Mr. C. H. Eldridge,* who are experts in the use of the

* COLIN G. FINK, Ph.D. and CHARLES H. ELDRIDGE, B.S. The Restoration of Ancient Bronzes and other Alloys. *First Report*, 1925. The Metropolitan Museum of Art, New York.

electric current in the restoration of bronze objects; but for safety, and with the simple appliances at the command of most curators of museums and other collectors, the treatment with zinc in alkaline, or it may be in acid, solutions will be found most generally useful.

A good example of the removal in this way of the hard and closely adherent incrustation is shown in Figs. 36 and 36A, which represent the bronze case for a mummified fish, before and after treatment. The fine detail work on the fins and scales is here admirably revealed.

Again, the inscription and detail on the much-corroded lamp (Figs. 37 and 37A) have been brought to light and the process of corrosion arrested. The active progress of the "disease" is taking place at the white parts of the picture and its effects are seen by the holes eaten in the metal in the cleaned specimen. Not infrequently it happens that it is necessary to clean such copper and bronze objects when, owing to the nature of the incrustations or to other circumstances, it is inadvisable or even dangerous to employ any solution having an acid reaction. To meet such cases the Rochelle salt method of cleaning was devised (*First Report*, p. 12; *Second Report*, p. 7), which gives excellent results and is highly spoken of also by correspondents. It need hardly be pointed out to chemists that its utility and safety depend on the fact that while it may attack and dissolve cupric oxide and the compounds derived from it, it leaves unchanged both cuprous oxide and metallic copper.

Where there is abundance of metal and the amount of corrosion not extensive, a solution of ammonium and stannous chlorides kept faintly acid with hydrochloric acid is most valuable, especially when it is desired to keep the specimen bright and metallic looking. Figs. 38 and 38A represent a statuette of Isis which has been thus cleaned. The interesting bronze mould for barbed arrow-

heads shown in Fig. 39, found at Carchemish, was given this same treatment. Besides its own particular interest as a specimen, the behaviour of this mould under treatment has brought out several points of interest in its past history and also has been the means of indicating certain precautions to be taken in treating objects made of cast bronze. When treated in the first instance it seemed to present nothing unusual in its structure or behaviour. The mould proper originally consisted of three parts in the form of similar longitudinal sections of a cylinder (Fig. 39A), of which only two were found along with some of the arrowheads cast in the mould. Each of the sections had a handle at right angles to the cylindrical face, giving it somewhat of the form of a hammer. After the usual treatment and a very thorough washing, the mould and arrowheads were exhibited in the museum. After a period of two years in the cases one of these parts was found to be showing signs of "disease" in a somewhat unusual form. Examination showed this to be due to the retention of some of the ammonium chloride by the porous metal, even after the prolonged washing. This porosity was found in its turn to be due to this one piece having been exceptionally porous, and its maker having endeavoured to remedy this by hammering with a blunt-pointed hammer. Where each blow fell the metal was hardened and compressed, the space between each depression thus produced remaining porous and capable of retaining the solution. In the course of time these little angular patches which had corroded most were rendered apparent and this accounted for the honeycomb like pattern which the "disease" presented in this case (Fig. 39C). The treatment of this mould forms an illuminating instance of how details in the manufacture of objects made over two thousand years ago may be brought to light by modern research.

Another case of light being thrown on the history of

manufacture of an important object is presented by the standard pint measure in the custody of the Standards Department of the Board of Trade. This (Queen Elizabeth) measure, dated 1602, is shown in Figs. 40, 40A and 40B. Although heavily varnished, small white incrustations were seen all over it, and these had increased in course of time to such an extent that this white substance was falling from the surface of the measure. Examination showed the incrustation to consist of the ordinary basic carbonate of lead. The question naturally arose as to how this could be formed on any object made of bronze. After the varnish had been removed, the lead carbonate was decomposed and the measure pickled in dilute sulphuric acid. After thorough washing and cleaning, re-examination showed that the measure as cast was of so porous a nature that it could not retain liquids, and its maker had therefore endeavoured to remedy this by dipping it in molten lead so as to fill up the pores. The excess of lead was then scraped off. Figs. 40A and 40B show well how the lead had been eaten out of the surface by atmospheric action, and also the marks of the scraping tool used to remove the excess of lead from the surface. A four-pound weight of Edward IV in the form of a thick disc which was also suffering in this way was found to have had a similar treatment before being used as a standard weight.

When objects, especially those of bronze, have the incrustations on them reduced, either naturally or in the laboratory, the reduced metal often forms a tough layer of pure electrolytic copper. Between the object and this layer is the unreduced oxide of tin. This thin layer of porous oxide retains with great persistence acid and salts and, unless these are removed, forms the starting point of fresh corrosion. This was well exemplified when treating some bronze pots from West Africa (Figs. 41 and 42). After cleaning and thorough reduction

of the coating of copper compounds the patches of the redder copper were shown up on the yellower bronze after polishing. This polishing was naturally done after prolonged washing, but on the day after the pots had been polished (about 24 hours) a distinct dullness was observed round these patches of reduced copper indicating the presence of impurities in their neighbourhood and the recommencement of tarnishing. This is shown by the light portions in Fig. 42, which indicate the polished copper which is seen to be surrounded with a dull area.

These pots showed also how their makers rendered them watertight when holes or very porous portions occurred in the casting. Inside the pots, before cleaning, lumps of metal were found fixed to the sides or bottom. These proved to be lumps of copper which had been inserted into the flaws and then hammered so as to close the holes by rivetting. The outside was then filed or scraped smooth. This is shown in Fig. 41 where the copper surface is easily identified surrounded by the bronze.

WOOD

THE preservation of wood, both dry and saturated with water, has raised many points of interest in deciding how best and most suitably the wood should be treated. In the case of dry wood which has been attacked in various ways by insects and animal life, much work has been done elsewhere and on a much larger scale. The questions which arise from the attack of insects resolve themselves usually into how to strengthen the wood, how to destroy any insect life in any phase of its existence whether as egg, larva, chrysalis or complete insect, and finally how to prevent any further attack by any insect pest. The strengthening of the wood is often attempted and also achieved by the application of glue or gelatine so as to fill up the channels and pores in the wood. This when dry does add very much to the strength of the wood, but in damp atmospheres or where there is the possibility of water reaching the wood thus treated there is always the probability of the gelatine becoming soft and also of its encouraging the growth of moulds which would bring about its destruction. One substance also recommended is paraffin wax applied hot, or even in solution, but it does not add much in the way of strength. It is, however, excellent as regards resistance to dampness and even liquid water, and any wood so treated is not likely to have any eggs deposited on it. One substance which seems to promise well is that solution of sodium silicate sold as "P.84." When this is applied at half or even a quarter of the strength as sold the wood becomes hard and strong when dry, and does not show any unpleasant efflorescence. The surface

is such that it is most unlikely that any beetle would lay eggs upon it and even if any larvæ were hatched on it it seems improbable that they would be able to attack wood so treated.

When very wet wood has to be brought into the dry atmosphere of Museums many points have to be taken into consideration. For example, when the piles from "lake dwellings" have to be preserved so as to undergo no change of shape and to retain the markings left by the tools employed by these ancient builders it is important that as little shrinkage or deformation as possible should occur. Experiments in progress seem so far to indicate that the sodium silicate solution described above gives very good results. This becomes dry and hard when the wood is thoroughly impregnated. To enable this to be accomplished in a waterlogged wood, is however, by no means easy with large specimens. When small enough to go into vessels of suitable shape which can be evacuated by a good air pump it ought to be possible to withdraw the air from the wood especially if the temperature be raised somewhat. On readmission of air to the vessel the silicate solution would be forced well into the pores of the wood.

One problem presented for solution is that of an old pumping cylinder and its piston which had been kept under water for perhaps 150 years. It seems doubtful whether it will be possible to limit the deformation so that the shrinkages will be so slight as to allow the piston to move in the cylinder after drying, when the direction of the grain of the wood in these two parts is considered. Instead of hardening and drying the specimens by treatment with sodium silicate, glycerine seems to be the most likely substance to give good results, especially if the object could be warmed to about 60° Centigrade in a bath of glycerine in a vacuum. The water would be

distilled out, and on the admission of air its place would be taken by glycerine which would never dry. A variant would be to use glycerine jelly (glycerine and gelatine) which, after application, could have the gelatine in the outer layers at least hardened by immersion in a solution of formaldehyde.

GLASS

IN many instances moisture is attracted by an object of glass or enamel, and may be observed in the form of little globules which, in aggravated cases, coalesce and flow over its surface in streams. This applies not only to specimens exposed to the outside air and weather, but is found to take place in certain types of glass in the museum, under conditions which seem specially regulated to ensure indefinite preservation. After this has gone on for some time it is observed that the surface of the glass has lost its original brilliance, and this can be seen more clearly by washing and thoroughly drying the specimen. When examined with a lens, the loss of brilliance is found to be due to a multitude of small pits in the glass. Enamels are likewise liable to decay in a similar fashion, though possibly in this case only one or two colours in a composite enamel may be thus affected. The cause of this abnormal behaviour is usually attributed to the use of too great a proportion of alkali, especially potash, in the mixture of components from which the affected glass has been made. This excess of alkali, being that over and above the proportion required to combine with the silica present, is held in a very loose state of combination, if combined at all, and attracts moisture and carbonic acid from the atmosphere, forming a strongly alkaline liquid, which attacks the transparent silicates of which the glass is composed, leaving calcium and other silicates in an opaque form. Such glass is often said to be " diseased," and this disease results from an unsound constitution.

Experiments made in order to determine the accuracy of this generally accepted explanation afford strong corroboration of it. Some badly "diseased" specimens were kept for several days in an atmosphere saturated with moisture and then washed. The wash liquid was strongly alkaline and gave the usual tests for the presence of potassium salts. The specimens were then kept in distilled water for several weeks, the water being frequently changed. When taken out and dried and kept in the ordinary atmosphere they showed great improvement as regards absorption of moisture, but when placed in a moisture-saturated atmosphere it was found that their tendency to attract water had not been eradicated. If the attraction for moisture is really due to the excess of alkali, the natural cure ought to be its removal by treatment with an acid. For certain reasons dilute acetic acid was first tried for this purpose, and proved to be a great improvement on distilled water, but it was found to be distinctly inferior to dilute sulphuric acid. This latter acid, by neutralising the alkali, and perhaps also because its potassium and sodium salts are non-deliquescent, seemed to cure the "disease" entirely. The strength of the acid employed need not exceed 1 per cent. After being thoroughly tested in a moist atmosphere, the specimens were once more thoroughly dried and given a coat of thin dammar varnish, which restores some of the original brilliance and forms an additional protection against further change.

A problem constantly arising in museums and of interest to collectors generally is the determination of the age or the source of specimens of glass. This is frequently solved by finding out whether the material is a lead glass or is free from lead. As a glass containing lead is much denser than one free from it, the usual method of deciding this is to determine the specific gravity of the glass. It is obvious, however, that this method is inapplicable

when the specimen contains hollow spaces or large air-bubbles, whether intentional or not. A method much easier in its application and of much greater certainty is to resort to chemical tests. If dilute hydrofluoric acid be applied to glass for a few seconds and the liquid tested with a solution of hydrogen sulphide, a black precipitate will be formed if lead is present in any appreciable quantity. The method of applying this test is to place a drop of dilute hydrofluoric acid on the surface of the glass, using a small camel's hair brush or a piece of wood to do so, and to leave it there for 15 seconds and then to add to that drop one of a solution of sulphuretted hydrogen. Perhaps an easier and even more sensitive method is to absorb the drop of hydrofluoric acid after its action on the glass in a piece of white blotting paper and apply to this spot a drop of sulphuretted hydrogen solution; the black stain produced when any lead is present is then easily seen. As a rule, a dilute solution of ammonium or sodium sulphide may be employed instead of sulphuretted hydrogen, since the amount of iron in any clear glass is so small as to give no appreciable colour in so short a time. As soon as possible after the test has been made the glass should be washed free from the hydrofluoric acid.

It need hardly be pointed out that glazes on porcelain, etc., may be tested in a similar way.

If the test be carried out as described above, no mark remains behind on lead glass and but a very faint one on glass which is free from lead. It usually requires examination with a lens accompanied by a knowledge of the spot selected for the test, to be able to detect any difference in the surface after the experiment has been made.

Besides naturally-occurring decay in glass, problems sometimes present themselves which have been occasioned by previous treatment of the glass, either in efforts to preserve it, or to modify its colour or render it more opaque. An example of this is to be found in the early

fifteenth century windows of the Lady Chapel at Wells Cathedral. Here a grey, very closely adherent coating was found on the *inside* of the windows. This is removable by scraping with a knife or similar instrument, and it is found that the glass beneath is practically intact and has preserved its original brilliant surface.

Analysis of the coating shows it to consist largely of calcium sulphate (65 per cent.). Silica is also present (15 per cent.), and the remaining 20 per cent. consists of water with a trace of organic matter. The only material suggested by the analytical results is cement of some sort, which must have been applied as a wash, either to hide or obscure the windows.

Many solutions have been tried to loosen or soften this coating, including the attempted conversion of the calcium into carbonate by soaking in sodium carbonate solution and removing the carbonate either by friction or by means of a dilute acid. Barium chloride solution was also tried in the hope that the barium sulphate which should be formed might be destitute of coherence and be easily removable with the surrounding silica. The best reagent so far discovered is a saturated solution of ammonium sulphate, which, as is well known, dissolves calcium sulphate. Ammonium thiosulphate was also tried for the same reason, but with only moderate success. The painting on the windows is brown oxide of iron fritted on to the glass, or very imperfectly fused to it. It is therefore impossible to use strong acids such as hydrochloric acid, which readily attacks the oxide of iron leaving only the pattern of the painting as a roughened surface on the surrounding brilliant surface of the glass. It might be mentioned that the body of the glass is sometimes amber coloured and sometimes bright green. In neither variety has the inside surface been *attacked* by the coating.

In many of the pieces examined, the outside surface of the glass is eroded in the usual manner, with rounded pits which diminish enormously the transparency of the glass. This can be mitigated by giving a coating of Canada balsam or similar varnish, but, unfortunately, such a coating would not withstand the action of the weather for any length of time, and would be costly to apply repeatedly.

THE STEIN COLLECTION

A LARGE collection of very various types and of varying dates brought from Chinese Turkestan by Sir Aurel Stein has been cleaned and preserved for the museum here and for the Indian Museum in Delhi. The photographs (Figs. 43–50) serve to illustrate some of the specimens which may be seen in the British Museum.

A large number were of mud, containing what may be termed a skeleton of straw or rushes. Of these, many were elaborately gilt or painted with many colours. The gilding and the colours were much obscured, sometimes almost altogether hidden, by similar clay or dried mud which filled up the hollows. Any attempt to remove this mud directly was almost certain to bring away the gilding and to destroy the typical moulding of the specimens. Here, again, the use of cellulose acetate solution proved invaluable. By giving several coats of this solution so that it penetrated into the porous stucco behind the gilding and into the colour layers, and then allowing it to dry hard and thereby fix the gilding to the underlying base, it was found possible to clean off this external deposit of earthen matter and so to bring back the gilding and colours almost to their original brightness by means of the solvent (usually acetone) applied with a brush and accompanied by gentle friction. This was especially so with a number of small images of Buddha. The toys, besides being of dried earth, were often of wood, either alone, or forming a framework to support the dried earth. Examples of these are seen in Figs. 45 and 46. In Fig. 44, which is that of the leg of a large figure, the straw bundle is plainly visible. Grotesque heads of painted wood and of dried earth are shown in Figs. 47 and 48, and these also show the straw

bundles. The usual museum term for the dried earth employed in fashioning these figures is "stucco," a term strictly applied to plaster of Paris (or calcium sulphate) which has set; this term, therefore, has not been employed to describe the figures.

From burial mounds many interesting objects, not usually found owing to climatic causes, were discovered existing in a marvellous state of preservation. Perhaps the most remarkable are the biscuits and cakes, some quite elaborate in form, which are shown in Fig. 50. Even the stains of the jam or similar preserve are still quite plainly seen after the lapse of 1100 to 1200 years. This wonderful preservation is due to the extremely dry and pure atmosphere of Turkestan. Among the objects found were the goggles or spectacles of metal pierced with numerous holes, which were placed over the eyes of the dead. These, when found, were dark green in colour and much tarnished. On examination they were found to consist of silver which had been alloyed with copper. They are shown in Fig. 49.

REFERENCE has been made in other parts of this Report to a most interesting collection of Roman remains recently excavated at Colchester. A few of the bronze objects are of unusual interest and they merit a short description here; they have all been subjected to treatment in the laboratory. One of great age, as is shown by its form, is a celt, which perhaps 1,000 years later has been adapted by its Roman collector or possessor to some much more recent purpose. This is shown by the deep longitudinal groove cut along one side, and by three knobs of a hard white metal let into that side, two on one side of the groove and one on the other. The loop of the original celt was broken. (Figs. 51 and 52.)

Another interesting object is the small bronze table with feet. The table was originally strengthened by the addition of two bars of bronze extending the whole length of the table which were soldered to the under side. In spite of this precaution the table-top was broken. (Fig. 53.)

The figure of the griffin (Fig. 54) is only one of a number of strikingly modelled figures of real and mythical animals which were found.

TEXTILES

CLOTH and tapestry of different kinds have presented various problems according to the source of the basic material, whether animal, such as wool and silk, or vegetable, such as linen and cotton. These, again, may be plain, or covered with pictorial representations which latter may depend for their effects on painting on the material itself or it may be on the use of threads of various colours.

Amongst the earlier problems presented was the strengthening and restoration of Chinese paintings on silk. Some had already been treated in China by mounting them on modern silk of suitable colour, probably with paste. This had apparently become brittle and so lost its power of retaining the painted silk in place. A solution ($2\frac{1}{2}$ per cent.) of cellulose acetate in acetone was tried and has proved quite successful and after five years the pictured silks seem as good as when the treatment was finished. No doubt celluloid solution would be a little tougher and therefore stronger, but it was considered undesirable on chemical grounds since there might be in this case a tendency towards decomposition by the action of light and air with consequent disfigurement of the delicate fabric. It is well to have all objects which are to be treated with cellulose acetate in as dry a condition as possible so as to minimise any tendency to produce a whitish or opalescent film. Should such appear it is easily removed by a tuft of cotton wool charged with acetone. Some tapestry-covered chairs were cleaned first by a vacuum cleaner and then by careful superficial washing with a soft cloth soaked in a mixture of 4 parts benzol with 1 part of methylated spirit which brightened them up considerably. Where the material will stand

it, a brush, not too soft, gives better results than a cloth for applying the cleaning mixture. This mixture was employed to remove the traces of grease and oily matters which are the usual substances by which dust and dirt are retained by cloth in its various forms. To strengthen the fibres and at the same time render them less ready to pick up and retain dust, the tapestry was given a coat of cellulose acetate solution. This undoubtedly took away some of the brilliance produced by the benzol mixture, a result probably due to the laying of the very fine fibres. The final result was most satisfactory in that it gave a very natural appearance to these 18th century chairs instead of the unnatural brilliance left after treatment with the benzol mixture, a brilliance which, it ought to be pointed out, could not be maintained in a London atmosphere. Cellulose acetate solution applied to a clean white cloth in the strength recommended above is practically invisible when dried, but communicates a slight harshness to the treated cloth. It might be well to point out here that preliminary experiments must be made before applying it to many of the forms of artificial silk, as well as to any coloured or dyed fabrics.

Where slight colour (brownish) is no objection and where strengthening of the fabric is of the first importance the solution known as "Duroprene" has been found most effective. This may be diluted with benzol, toluol, or xylol so as to give a suitable strength and limpidity. It may be diluted to one half, one third or even one fourth of its ordinary strength.

A series of experiments made at Luxor for the best substance with which to strengthen the very frail pall which was over one of the inner shrines in the tomb of Tut-ankh-Amen led to the choice of "Duroprene," and the diluent used was in this case xylol on account of the high atmospheric temperature. Several other substances were tried, but none strengthened the fabric so much and

the slight brown colour was not a disadvantage in this case as the pall had acquired a dark brown tint. After treatment with the "duroprene" solution it was practically impossible to distinguish a treated from an untreated piece except as regards the great increase in strength. The whole of the dissolved matter seemed to be absorbed by the fibre and there were no remaining films between the various threads. When solutions of cellulose acetate and celluloid were tried they invariably left films which connected the fibres together and so produced an opalescent effect which was objectionable and altogether foreign to the material.

In this connection the microphotographs of linen cloths from the tomb (Figs. 55, 56 and 57) may prove of interest.

"Duroprene" solution has also been employed with success in strengthening the cloth in some of the early aeroplanes now in museums which, either from the dopes employed or from other reasons, had begun to fall to pieces.

" FAKES "

IN a collection so vast as that of the British Museum it would be strange if interlopers in the form of fakes did not now and again find their way into the cases for exhibition as genuine illustrations of art and craft. One of the most interesting, which had been presented to the museum by a well-known collector, purported to be a Mexican funerary vase. In the lower part, the surface of what was supposed to be *stone* began to flake off in a very peculiar fashion, taking place as it did in no particular direction and not parallel to any lines due to natural stratification. Examination of the lower portion showed it to be covered with a layer of sand and glue which had been skilfully applied to simulate a sandstone surface. Further examination showed how extensive as well as how clever the additions to the fragmentary original had been. It had completely deceived the donor of several other genuine antiques of similar character who was an expert on such subjects. What had been added was of the nature of Portland cement and the whole was given a final coating of a uniform grey colour of sand and glue to represent a fine-grained sandstone. Unfortunately for the faker, but fortunately for the cause of truth, the alternations of dry and moist days caused the coating of sand and glue to crack and peel off and reveal the fraud. The Figs. 58 and 58A show this specimen before and after investigation. At the lower right-hand corner of Fig. 58 the peeling which led to the detection of the fraud is clearly seen. Fig. 58A shows how little of the object was genuine and how much had been added to bring it up to the usual form presented by such objects.

A case of quite another kind, but which resembled the above in that it contained a substratum of genuine

material which had suffered so much from bad treatment that there was no chance of selling it in an untouched condition, was one of a valuable set of Limoges enamels presented to the museum by a well-known collector. It had been regarded by those in charge of these enamels as an example presenting doubtful features (Fig. 59). The reason for this was not discovered until a critical examination was called for by this example behaving as no other enamel had done. Blisters began to appear on the surface and these on breaking showed the well-known green colour of copper compounds just as in the "bronze disease" (Fig. 59B). Examination under the microscope indicated what seemed to be a somewhat reticulated coating of varnish. Application of methylated spirit on a tiny spot of what appeared to be a beautiful dark blue part of the enamel produced a pure white spot at once. Examination of the blisters showed that they also had a pure white layer overlying the copper. The investigation finally showed that what remained of the original enamel had been added to by applying a thin layer of plaster of Paris which was painted upon by brilliant varnishes charged with suitable pigments, and the whole then varnished over to give a brilliant and uniform surface. This was done with such consummate skill as to deceive even an experienced collector. The blisters which aroused suspicion as to genuineness were due to the salts in the plaster of Paris attacking the metallic copper and producing a notable increase in volume at these points of attack.

The subject of the picture is "The Entombment," and it is quite sufficient to look at the face of the Virgin and the right foot of the dead Christ to understand why suspicion as to its genuineness and value were aroused. After cleaning, its genuineness was no longer in doubt (Fig. 59A), but the effects of its rough treatment in the past were clearly revealed.

A specimen of yet another type, namely, a bronze vessel (Fig. 60) which was showing signs of active corrosion, was placed in sodium sesquicarbonate solution as recommended above. It had not been long in this solution when it came apart into two pieces (Fig. 60A). These were easily seen to be pieces of two entirely different objects which, though they were of no use or interest separately, when cemented together and the joint cleverly hidden by putty-like material and painted a suitable green all over, gave an object unique in its design, although not differing sufficiently from similar specimens to arouse active suspicion. The figures explain themselves. The above examples suffice to show that in cases of doubt as to the authenticity of objects presumably antique, expert scientific examination may afford valuable and sometimes conclusive evidence.

ALTHOUGH most of the solutions and other preparations recommended in the foregoing pages may readily be prepared by curators who have simple laboratory conveniences at command, it may prove useful to give the names of some of the preparations on the market which have been used with success in the work at the British Museum Laboratory. A few hints as to the use of apparatus of a simple nature are also added.

For treatment of engravings and printed matter generally which involves bleaching, the most useful vessels are the *papier-mâché* dishes used in photographic work. They are lighter than the earthenware ones or those of enamelled steel, are not liable to fracture, and cannot give rust spots as do the latter when the enamel chips off.

Brushes can be obtained in infinite variety, whether as to size or softness or hardness. It may save trouble to point out that for use in caustic alkali solutions, brushes with bristles of vegetable origin must invariably be used, and for the rubbing of coins and similar small objects what are known as "Egyptian tooth-brushes" are very convenient. They are made of a fibrous wood frayed out at one end for about 10 or 15 millimetres. The usual diameter is about that of an ordinary lead-pencil, but larger sizes are also made which are quite short and fit into a ring-shaped handle.

For some purposes, glass-haired brushes such as are made and sold for ink-erasers and for the retouching of photographic negatives are of great utility.

Cotton-wool pads are in constant demand for gentle washing and for the application of solvents and similar

purposes. These may in many cases be held simply in the hand, but this is inconvenient and undesirable when the solutions attack the skin. The best way to make a simple brush of this material is to take a tuft of the cotton-wool and tie a piece of string round it, leaving two long ends; thread these ends through a piece of glass tube (which ought to have the sharp edges taken off by heating in a flame), and pull the string so that the cotton-wool forms a tight plug and pad at the end of the tube. If a rounded-end pad of closer texture be wanted, this is easily obtained by pushing a tuft of the wool through a glass tube until it projects sufficiently beyond the glass. Of course, metal tubes can be used in place of glass. Copper tubes, for example, would be employed when hydrofluoric acid was being used.

Zinc metal is used in several forms, as zinc dust, zinc powder, and granulated zinc. The first is an extremely finely divided form and must be bought. It ought to be fresh, as some samples are so active that they oxidise spontaneously and so become useless even in a closed bottle, the grey-black powder becoming almost white. The powder form is prepared by melting zinc in a ladle and pouring it into a mortar, preferably of iron, and stirring it vigorously whilst solidification is taking place. The zinc is then easily broken up into a coarse powder which, for convenience, may be sifted into different degrees of fineness. In this condition it is probably in its most useful form for the treatment of bronze and other objects in conjunction with caustic soda solution. The ordinary granulated zinc is made by pouring molten zinc from a height into a pail of cold water, then draining and drying it thoroughly before storing it. In this form also it is very useful for metallic reductions when used either with caustic soda solution or dilute acids.

"Pyruma putty" has been mentioned when treating

of heavily-rusted iron objects. After being heated and dried it sets very hard. It must be applied in thin layers as thick patches do not seem to harden readily throughout. Similar results are obtainable by the use of kaolin (China clay) made into a paste with sodium silicate solution. This can be tinted to any desired colour by the addition of a suitable pigment.

The question of cements for the great variety of purposes required in a museum is far too large for treatment in detail here. A very useful one may be made by dissolving celluloid in a mixture of equal volumes of acetone and amyl acetate. This may be made of any consistency desired and may be strengthened and improved for some purposes by the addition of substances like gum dammar in a suitable solvent such as benzol. For most purposes, however, collectors will prefer to employ a cement of similar nature called "Necol," which is put up in collapsible tubes and is very easy to apply. Applying it as stated in the directions given on each tube, or applying to the surfaces to be joined a coating of celluloid varnish and allowing this to dry thoroughly, far stronger and better joins are made than those ordinarily made with shellac. "Necol" when dry is unattacked by water and is therefore much to be preferred to any form of transparent cement based on gelatine.

Solutions of cellulose acetate and of celluloid are of very great value and are amongst the most useful varnishes and cements. The strengths for cellulose acetate which are most frequently employed are 1, 2½, and 5 parts in 100 parts of acetone. For most purposes good commercial acetone is quite good enough; for delicate work, however, redistilled acetone should be used. The solvent for celluloid which is most used is, as has been stated, a mixture of equal volumes of acetone and amyl acetate, the addition of the latter being necessary in this case. As regards strengths, those similar to the ones

suggested for the acetate will be found most generally useful. Old photographic films do admirably for the celluloid, but before use the gelatine coating must be removed from *both* sides of the film. If this is not done a troublesome deposit of thin gelatine films will settle out from the solution.

Celluloid films give a tougher and more transparent film than cellulose acetate, which latter is apt to become opalescent if the objects to which it is applied are at all damp. The acetate is much less combustible than the celluloid film, but for most purposes this is not of importance. As the celluloid is made from cellulose nitrates, celluloid solutions should not be used with coloured objects as there is always the possibility of the nitrates being decomposed by light, especially in conjunction with damp.

Plaster of Paris is largely used for making backings and supports for many objects where the presence of water is not an objection. Only the purest brands of plaster should be used and none should be employed which give more than a quarter of a gramme of soluble matter per 100 cubic centimetres when 3 grammes are added to a 100 cubic centimetres of water. Several quick-setting brands are sold which contain alum and other soluble substances. These may give rise to serious trouble owing to their crystallising out and breaking up the surface of specimens to which such samples may be applied. It often happens that a backing or a filling is required which must contain no water. Such a substance is readily made with celluloid solution and various substances in the form of coarse or fine powders. Such fillings are especially useful when they have to be applied to objects impregnated with cellulose acetate or celluloid. For example, some large Chinese pictures on dried mud or clay which were in pieces had to be mounted and retained in their places in wooden frames so as to prevent vibration.

These were treated at the back with celluloid solution to prevent the crumbling of the clay and then embedded in a paste or putty made of sand and 10 per cent. celluloid solution. This sets into a hard mass with just sufficient elasticity, when dry. A rod made of this mixture a foot in length and having a half-inch square transverse section gives just a sensible amount when attempts are made to bend it. Other substances which for the above purpose were not so efficient were kieselguhr and kaolin. Saw-dust is a very useful substance to use in conjunction with celluloid, especially when the mixture has to be applied to wood. A mixture of sawdust in various colours with cellulose acetate or with celluloid is on the market as a commercial product. The former is sold as "Non-Inflammable Plastic Wood," and the latter simply as "Plastic Wood." An excess ought to be used as the pasty mixture shrinks appreciably on drying, but it sets so hard that it can be cut, planed and worked generally like wood when quite dry. It may be noted that the celluloid-sand mixture recommended above can be prepared in such concentrations that no appreciable shrinkage takes place, the product resembling a piece of sandstone.

"Duroprene," already mentioned in connection with textiles, seems to be a solution of a chlorinated rubber and is an excellent varnish for the protection of metals from rust or corrosion even after prolonged immersion in water and dilute acids. It dries to a tough and non-tacky film which takes paint and varnishes well.

For a filling for metal, especially wrought or cast iron, a preparation sold as "Mendeesi" is very useful. When properly applied it sets very hard and can be filed, ground and polished. It contains no ammonium chloride, and does not rust to any appreciable extent. It consists largely of finely divided iron mixed with calcium sulphate and some phosphate.

"Plasticine" for modelling is useful in many ways,

such as for holding together broken objects in their correct position after applying a cement until such time as the latter is hard enough to take the strain. It is useful also for making moulds and taking impressions and these moulds are very suitable for making plaster casts as the plaster does not adhere to the greasy surface of the plasticine. For large models in a warm climate it is not to be recommended. This was shown by the gradual deformation of the large models of the battle-fields in Northern France in one of the Australian museums. Experiments made here showed that this could be prevented by applying a coat of celluloid varnish (5 per cent.) which formed a tough skin able to resist change of shape.

Plasticine is sometimes applied in museums to keep small objects in their places on glass shelves especially where these are subjected to vibration. It should not be used where the objects are of ivory or of any substance of a porous nature as the plasticine is apt to give up some of the "vaseline" or greasy constituents to the objects and cause brownish stains.

In the treatment and repair of objects made of leather it is often necessary to fill up cracks and gaps. For this purpose gutta-percha may be used when softened by heat. To ensure its secure adhesion to the surface of the leather the latter should be coated with a solution of gutta-percha in chloroform. Another substitute for leather suitable as a filling is what is known as "Chatterton's Compound." This is made into a very stiff semi-liquid paste with carbon disulphide and applied to the cracks in this form. The gutta-percha may be used in its ordinary brown form which looks very like leather, but sometimes it may be useful to have it a pure white and this is sold in small rods for dental purposes.

No collection of notes would be complete without some reference to the difficult problem of patination. The problem is difficult because of the different composition

of the metal and alloys and of the treatment to which they have been subjected. If we have to deal with a metal such as copper much will depend on its purity, that is, its freedom from other metals. The pure electrolytic copper deposited from copper sulphate ought, one might suppose, to be ideal. It is just because of this purity, however, that difficulties arise.

As has already been pointed out the exquisite patina found on many bronzes owes its beauty and its solidity to the presence of oxide of tin coloured by compounds of copper. Pure copper therefore cannot be expected to give rise to such a coating.

Again, many bronze objects are not homogeneous, and consist in one part of an alloy richer or poorer in tin than that in another even when cast at one time. It is not uncommon to see side by side a white alloy along with a yellow alloy, the separation resembling that of a mixture of oil and water into layers after having been thoroughly mixed. Again some parts may have been converted either wholly or partially into a mixture of copper and tin oxides.

Where there is much metal remaining, and it is only in such cases that it is worth trying to produce by chemical means a patina resembling that which results from the slow action of natural agents, the usual method is to subject the metallic object to the action primarily of acid fumes so as to form an adherent layer of copper compounds, the colour of which may be modified later by the action of salts or alkalis.

When a simple blackening or a grey tint is sufficient, a very dilute solution of sodium sulphide is the simplest and best reagent. Enough solution should be used so as to cover completely the object to be coloured. For success it is essential that the metal be bright and quite free from grease of any kind. The action is simply to form a film of sulphide over the metal. Other substances

used to produce films are solution of the chlorides of arsenic, antimony and platinum which deposit these elements on the copper, bronze or brass. A similar result may be attained by the use of a dilute acidified solution of tellurium potassium chloride which gives a very permanent and pleasing grey black colour.

What is difficult to obtain upon any restored bronze is the green patina, and especially to have it cover the whole surface in a uniform and satisfactory manner. The usual procedure is to apply to the surface an acid, either in the liquid or in a gaseous form—in the former case either by immersion or by means of a brush or a tuft of cotton-wool, in the latter by suspending it in a closed jar along with a dish containing the acid solution, which must be of such a strength and nature as to give off fumes at the ordinary atmospheric temperature.

In spite of a very large number of experiments, it is impossible to recommend any one solution as *certain* to give good results. One which has in many cases been very successful is a solution containing ammonium chloride (sal ammoniac) and perchloric acid. For pure copper and alloys which contain but little tin the addition of stannic ammonium chloride is useful, as it provides a body of stannic oxide which assists in the foundation of a natural patina. Acetic and lactic acids in conjunction with ammonium-chloride solution often give excellent results. After the action of the acid mixture, followed by prolonged washing, the colour may be changed considerably by immersion in caustic soda or in sodium carbonate or bicarbonate solutions, the caustic solutions tending to give a blue rather than a green tint to the copper compounds. For gaseous treatment acetic acid has been recommended, followed by fumigation with ammonia (Fink and Eldridge, see p. 40). One of the most successful experiments was made with a bronze hand cleaned by momentary immersion in nitric acid, followed by dilute sodium sulphide,

and then washing and drying, and finally suspending it over diluted hydrochloric acid to which some potassium chlorate crystals had been added. The chlorine and oxides of chlorine produced a very hard patina of a dark green colour which has remained unchanged in the laboratory for five years.

Another very good mixture which gives a green coating which adheres well is a solution of potassium binoxalate and ammonium chloride in the proportion of 4 parts of the former to 15 parts of the latter in about 280 parts of water.

There is no doubt, however, that after the cleaning and thorough washing of the bronzes, the safest and most expeditious method, and that most under control, is to apply a suitable colouring or paint consisting of copper carbonate suspended in shellac varnish. Any shade from the bright green of malachite to the deep blue of azurite, is thus available. In this way much more artistic effects are readily produced. It may be objected that this is merely "faking," but it is not really more so than by producing on the surface a layer of copper compounds of a green colour, even if it be done by purely chemical means. It is safer in that no corrosive chlorine compound is left in the metal, however porous, and the shellac varnish is an admirable protective coating, however damp the atmosphere may be.

With regard to the preparation of stannous chloride solution for the cleaning of objects of bronze and metallic iron, granulated tin may be dissolved in hydrochloric acid (concentrated commercial acid) diluted with an equal volume of water, or solid stannous chloride may be dissolved in water to which a tenth part of its volume of concentrated hydrochloric acid has been added. This should be kept in a good stoppered bottle along with some granulated tin. For use, a strong solution of ammonium chloride should be added when and as required. Some

workers have reported that they have been troubled by the stannous chloride solutions gelatinising, but when prepared in either of the ways given above this has never been found to occur.

In making up solutions, it is always advisable to conduct operations in a fume cupboard or under some form of specially constructed draught hood; when such is not available, it is preferable to work in the open air or in a very well ventilated room. Special precautions must always be taken to ensure that acids and strong alkalis do not come in contact with the skin or clothes; if such an accident should occur, immediate steps must be taken to neutralise the corrosive agent, ammonia being liberally applied in the case of acid burns and vinegar in the case of attack by caustic alkali. After the affected parts have been rendered neutral, they must be washed very thoroughly in running water.

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FIG. 1.

FIG. 1A.

FIG. 2.

FIG. 2A.

FIG. 3.

FIG. 3A.

Fig. 4.

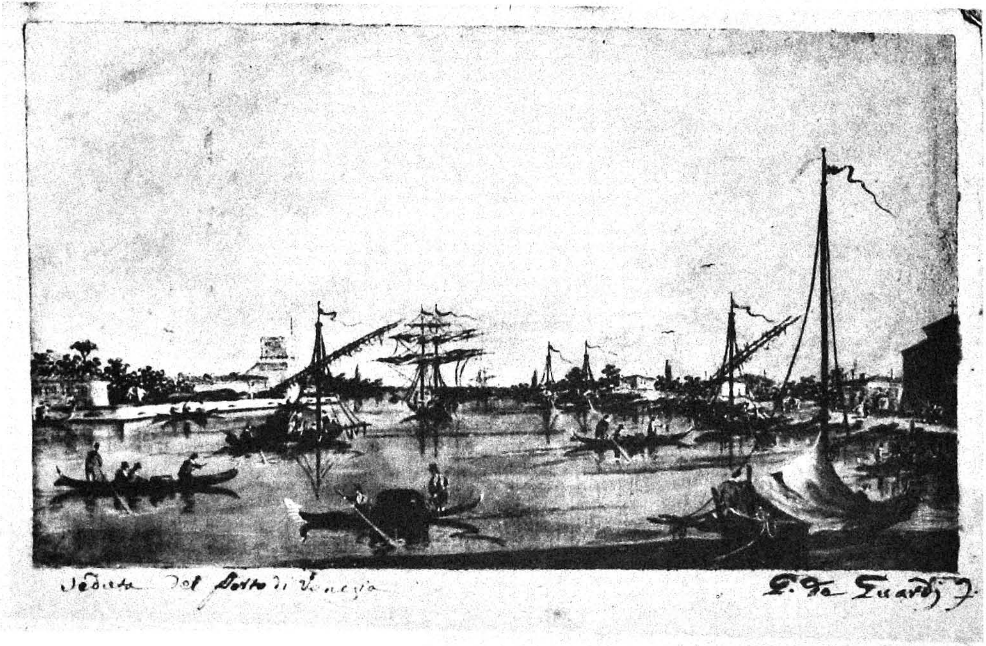


FIG. 4B.

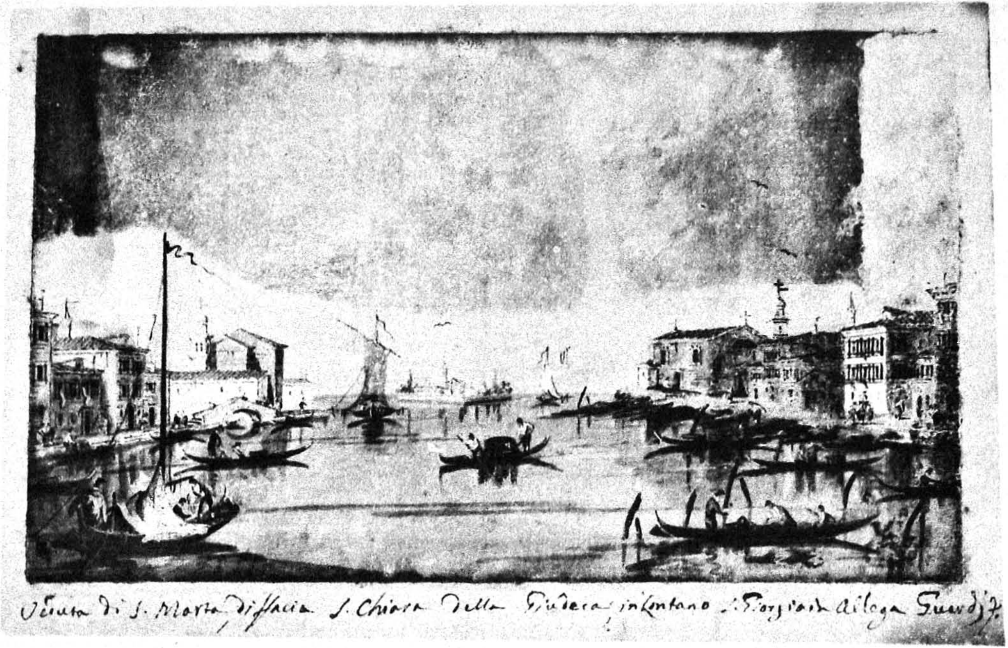
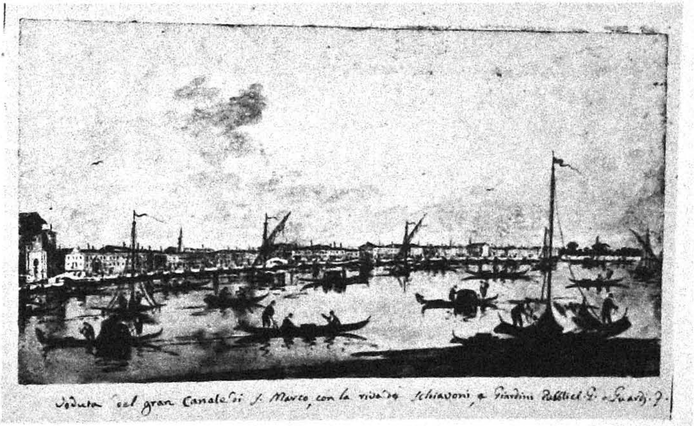

Veduta di S. Marta, diffaccia S. Chiara della Giudeca, in lontano S. Giorgio in Alega Guardi f.

FIG. 4A.

FIG. 5.



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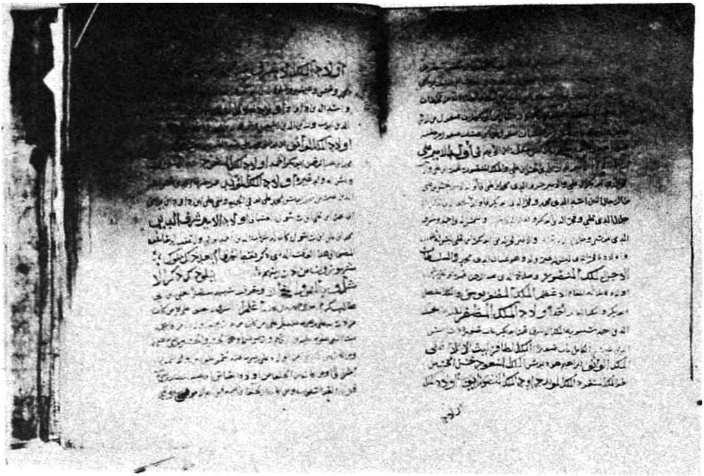
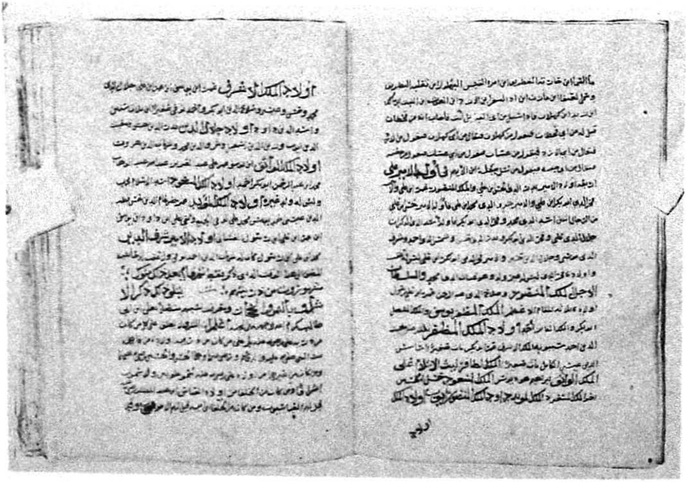


FIG. 6.



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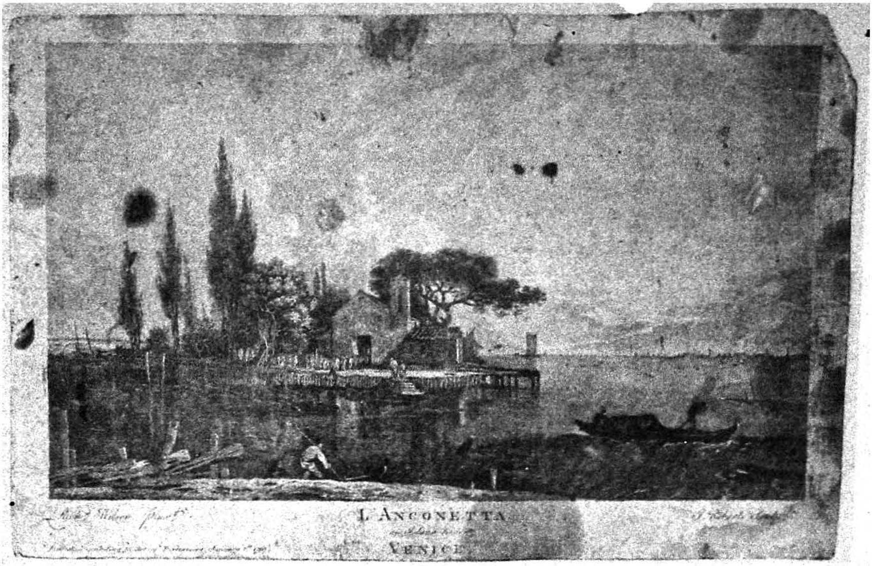

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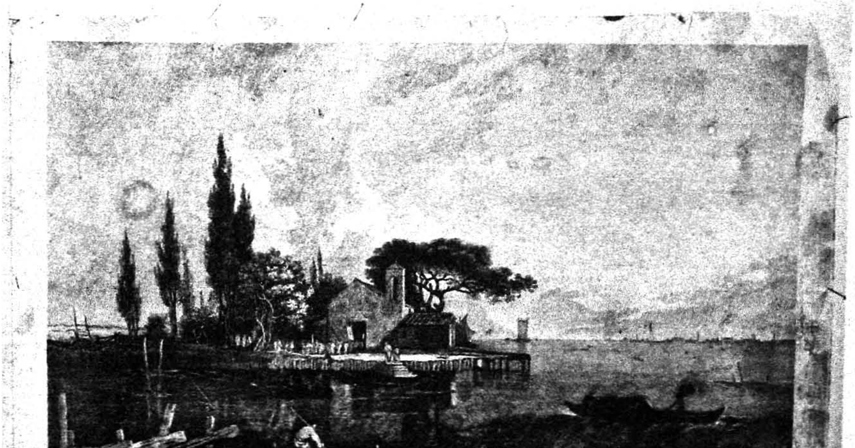

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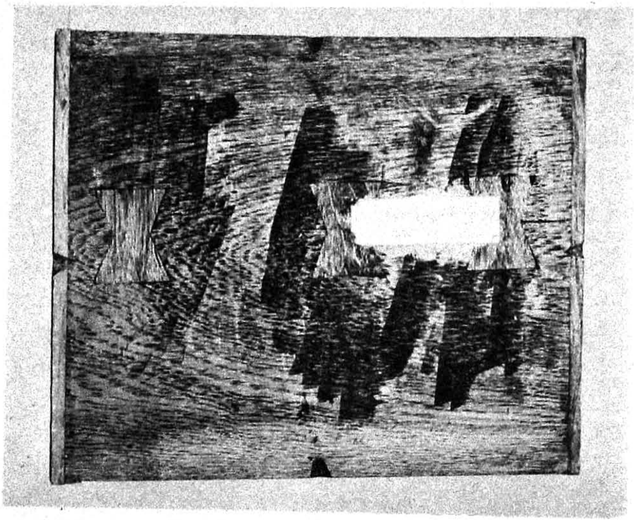

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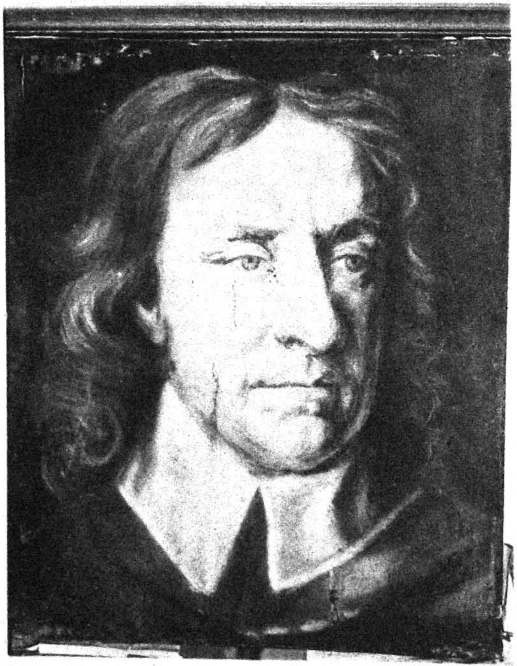

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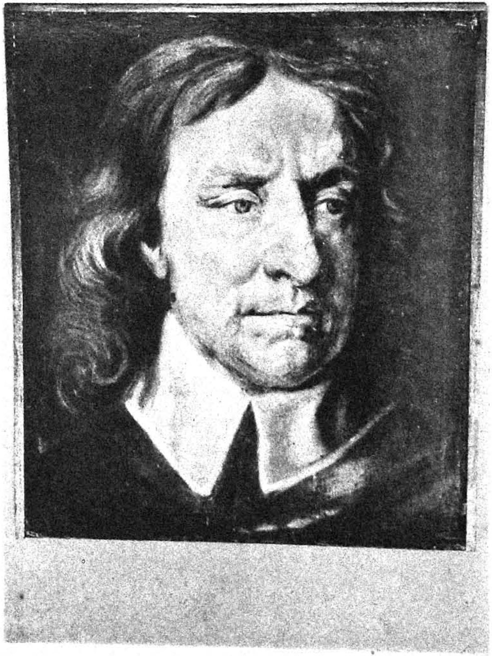


FIG. 9B.

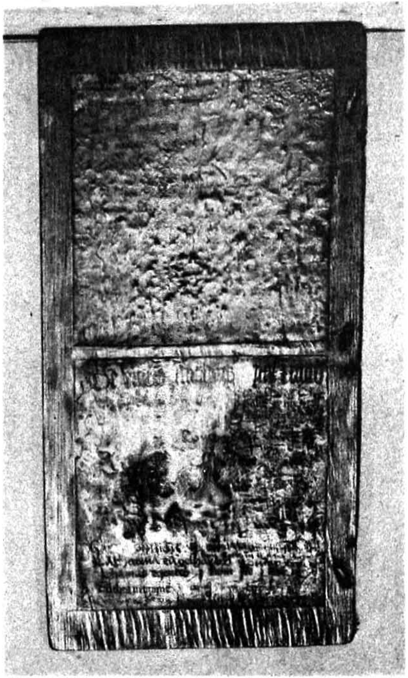
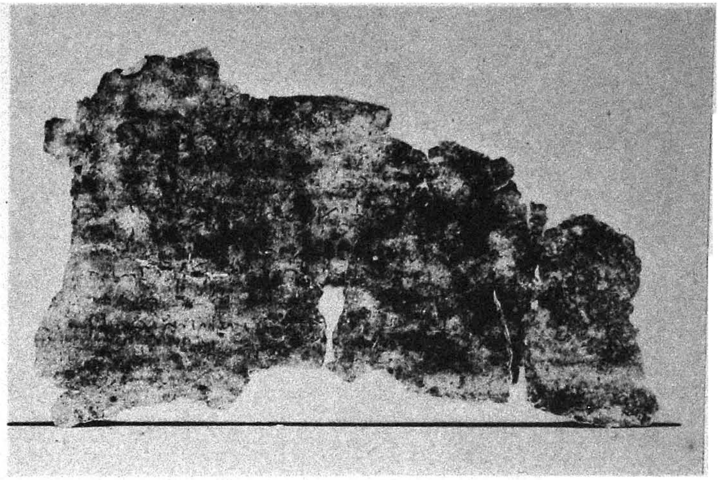


FIG. 10.

FIG. 10A.



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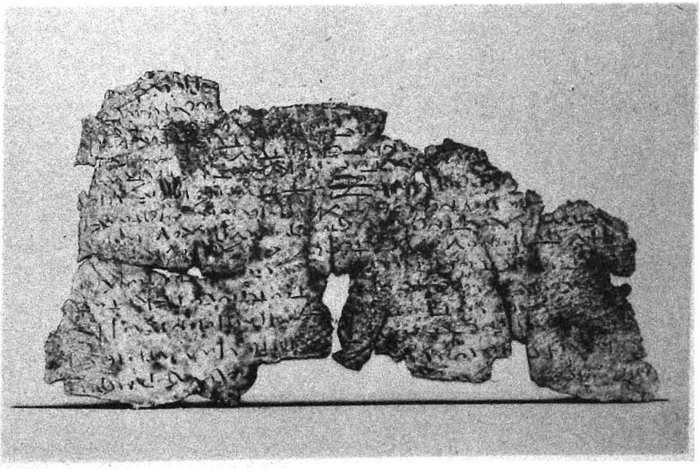
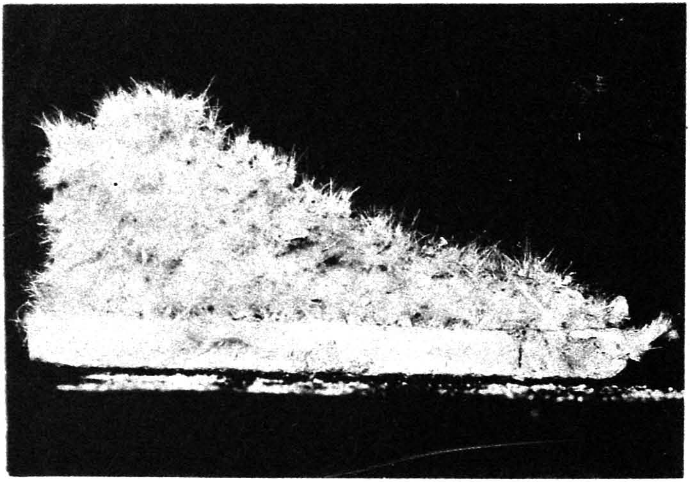


FIG. 11A



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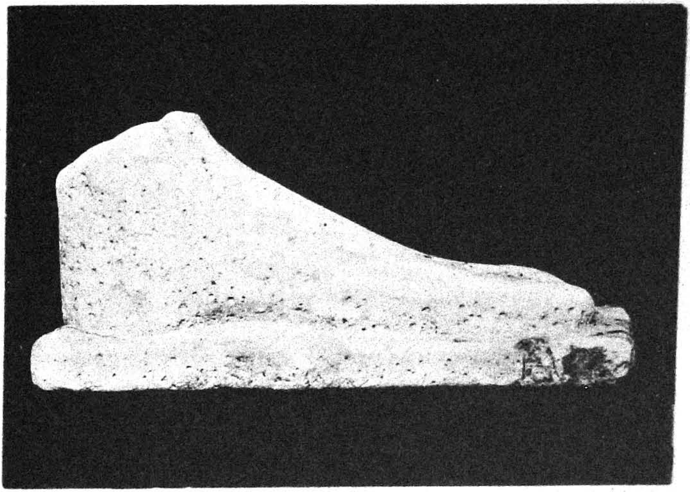


FIG. 12A.

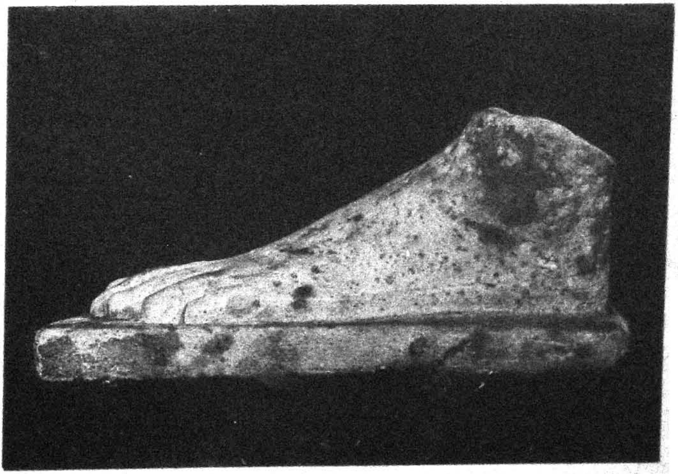


FIG. 12B.

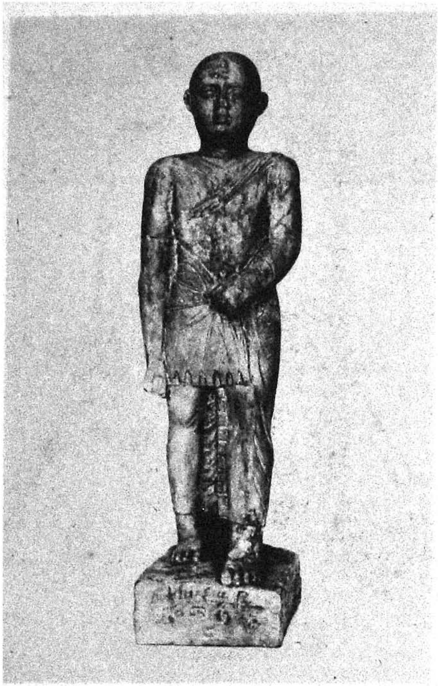


FIG. 13.

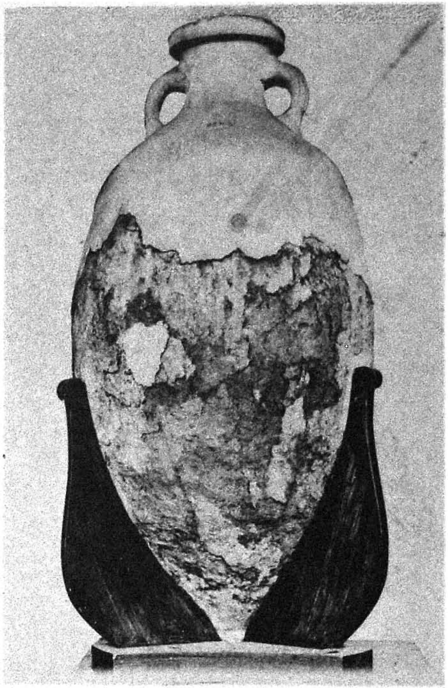


FIG. 14.

FIG. 15.

FIG. 15A.

FIG. 16.

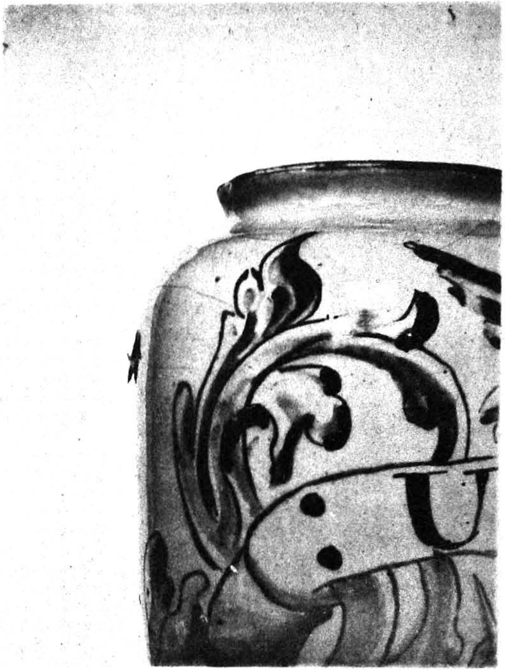
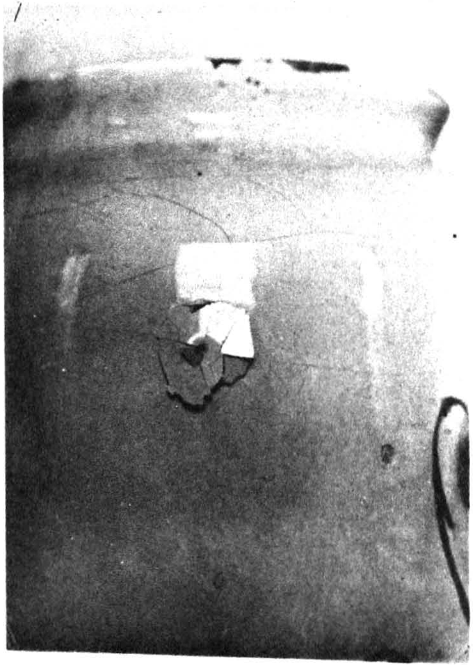


FIG. 16A.



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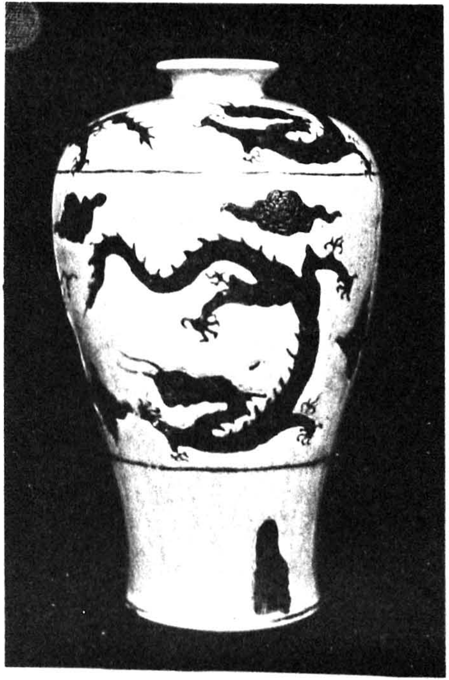


FIG. 17.

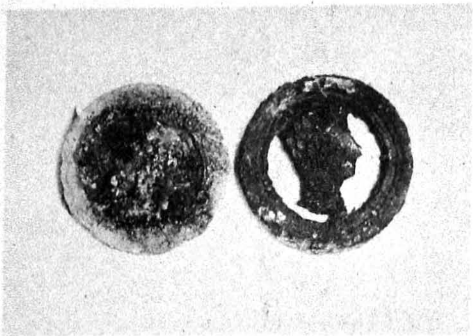
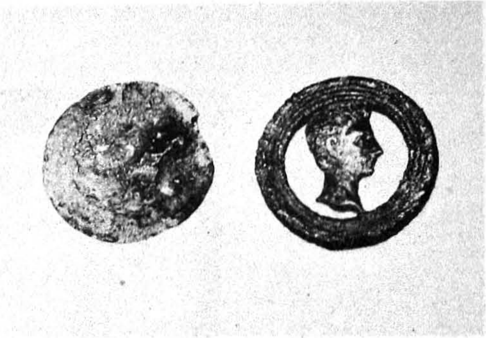


FIG. 18.



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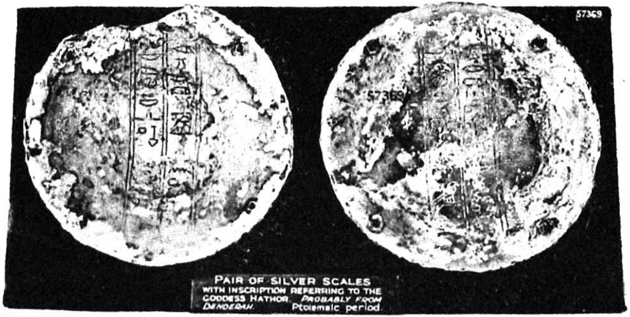
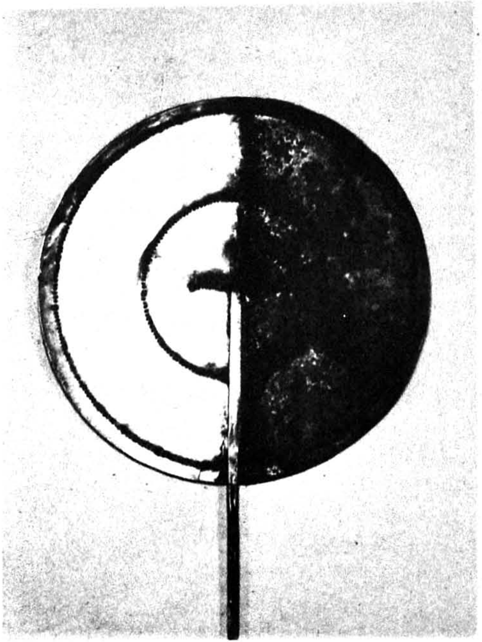

57369
57369
PAIR OF SILVER SCALES
WITH INSCRIPTION REFERRING TO THE
GODDESS HATHOR. PROBABLY FROM
DENDERAH. Ptolemaic period.

FIG. 19.

FIG. 20.



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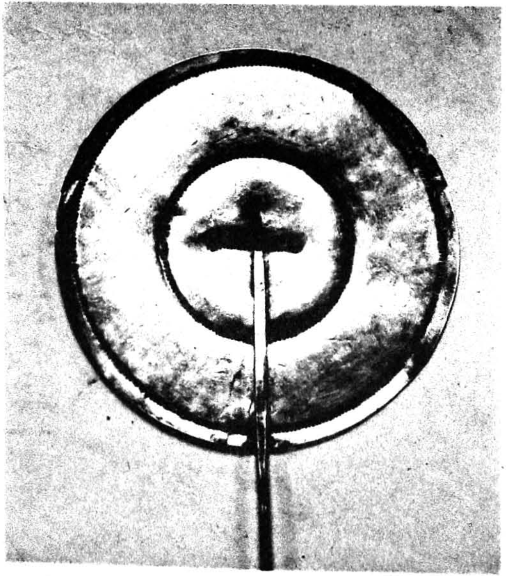


FIG. 20B.

FIG. 21.

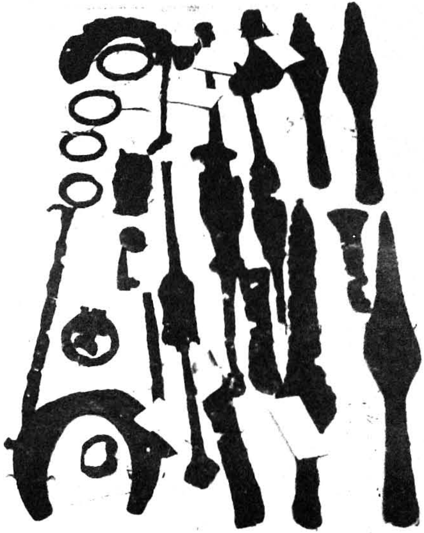


FIG. 21A.

FIG. 22.

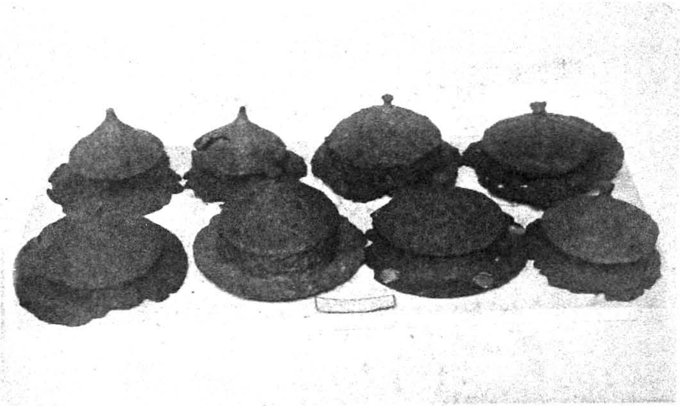
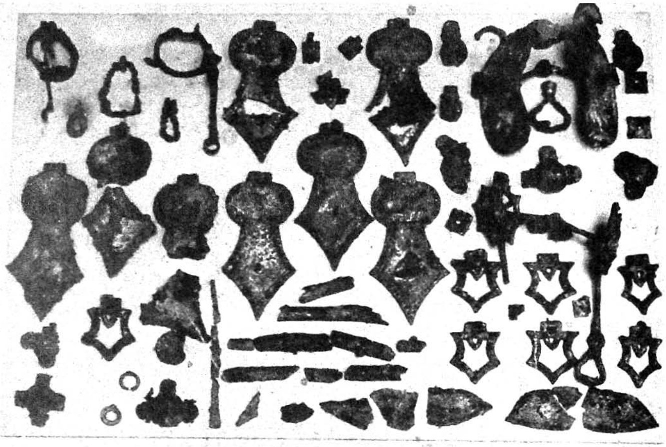


FIG. 22A.

FIG. 23.

FIG. 23A.

FIG. 23B.



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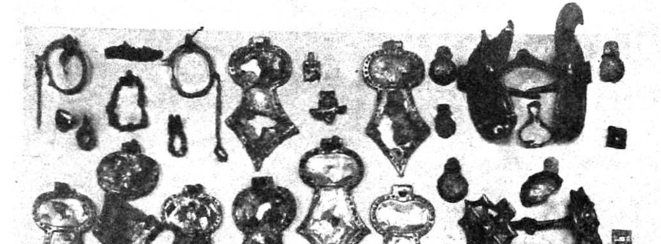


FIG. 24A.

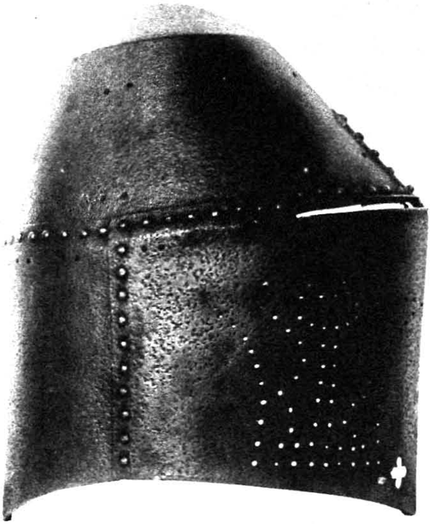


FIG. 25.

FIG. 26.

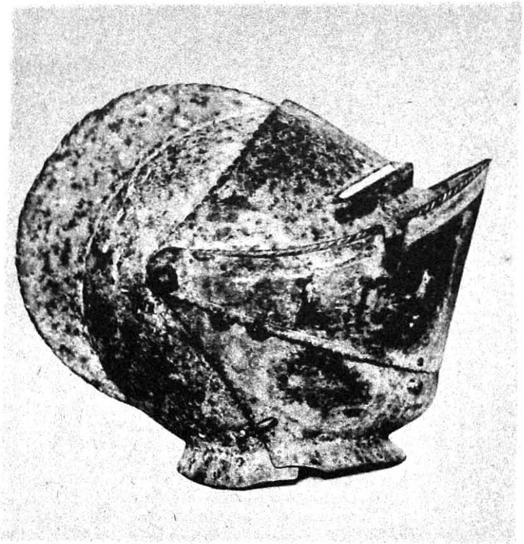


FIG. 27.

FIG. 28.

FIG. 28A.

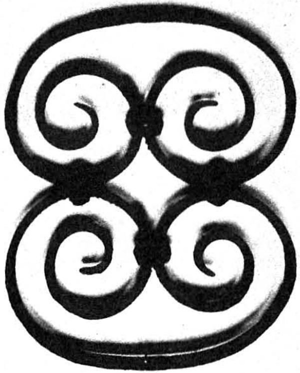


Fig. 29.

Fig. 30.

Fig. 30a.

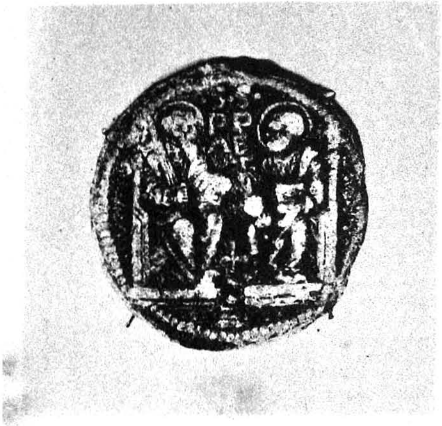
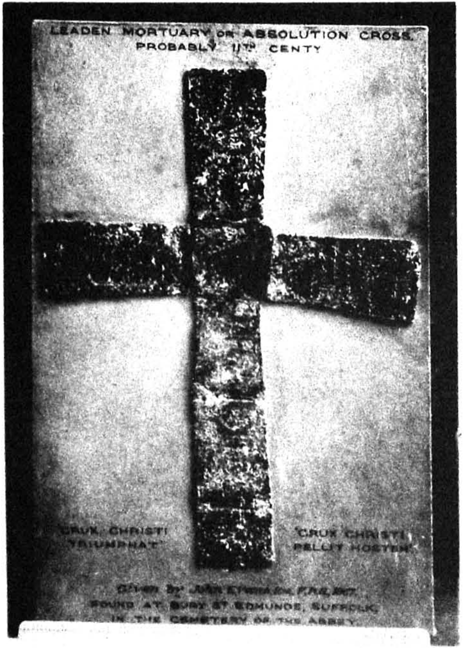


FIG. 31.

FIG. 31A.



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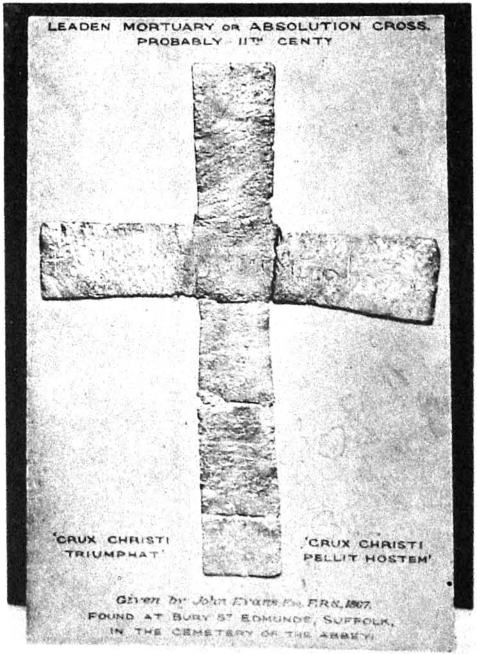


FIG. 32A.

FIG. 33.

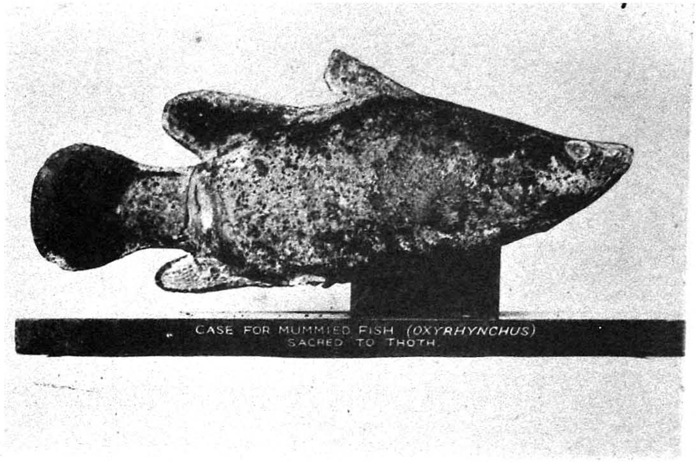
FIG. 33A.

FIG. 34.

FIG. 34A.

FIG. 35.

FIG. 35A.



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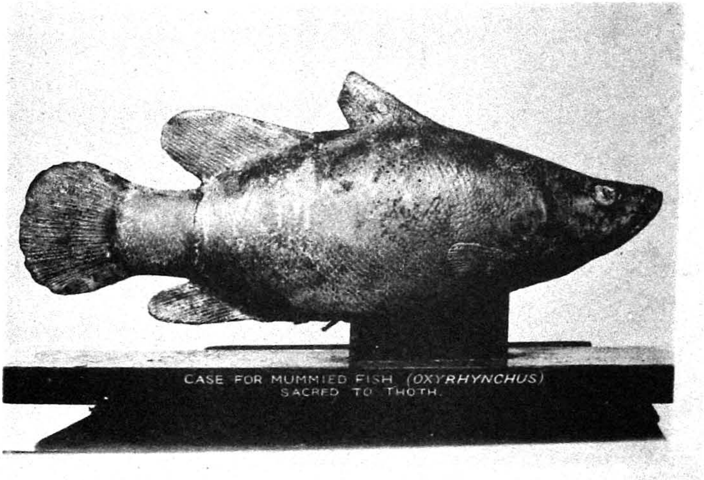


FIG. 36A.

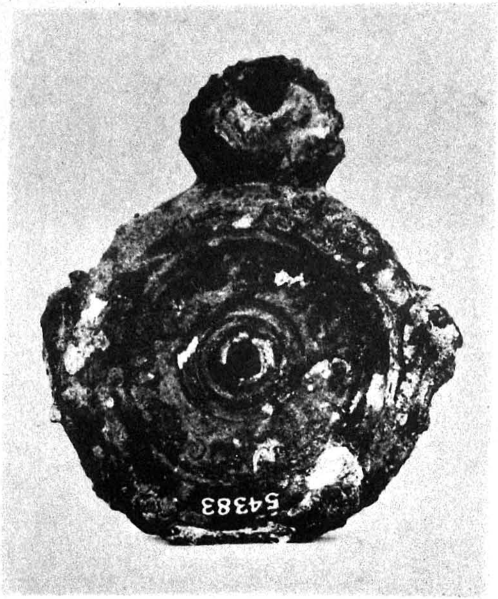
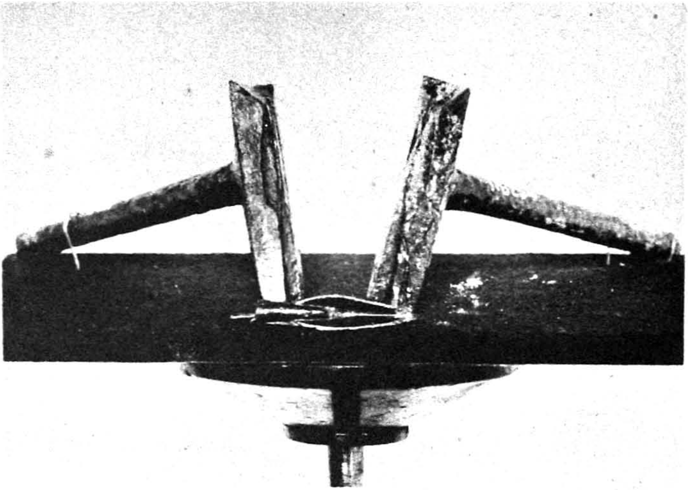


FIG. 37.

FIG. 37A.

FIG. 38.

FIG. 38A.



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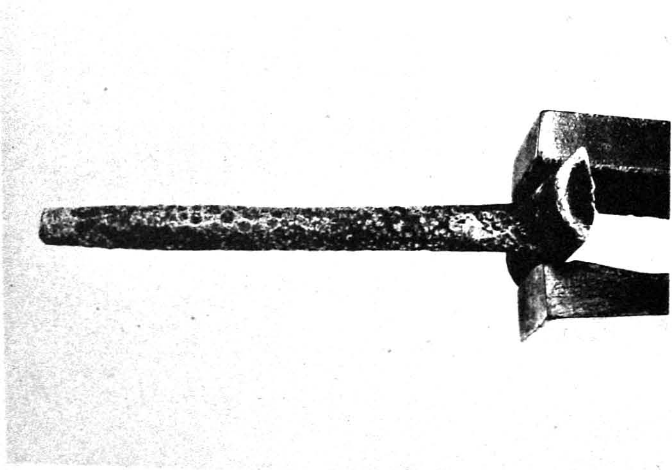

FIG. 39A.

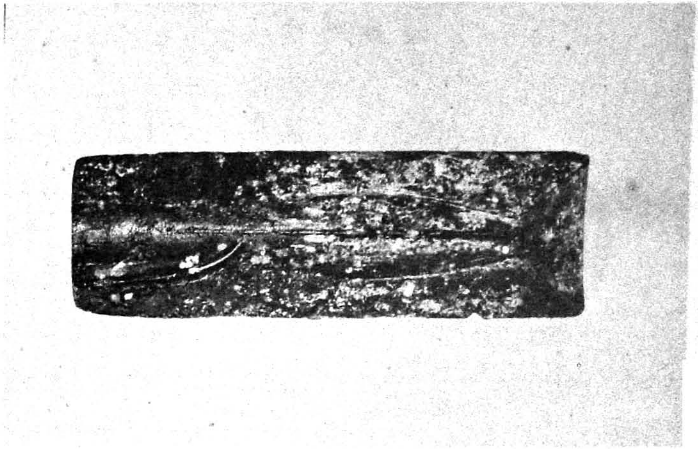

FIG. 39B.

FIG. 39C.

FIG. 40.

FIG. 40A.

FIG. 40B.

FIG. 41.

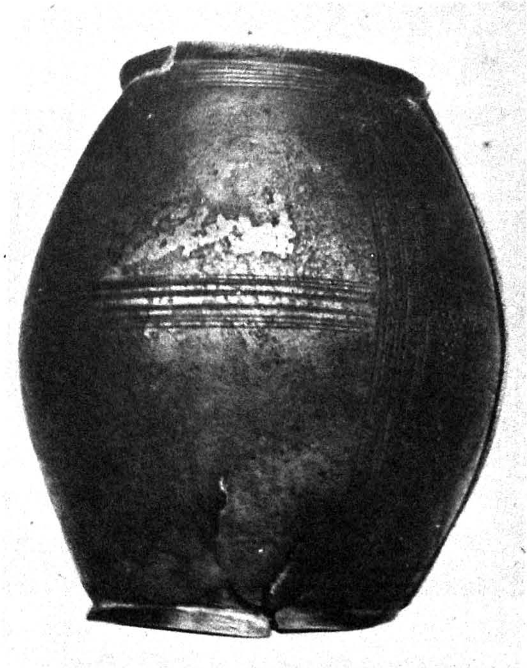

FIG. 42.

FIG. 43.

FIG. 44.

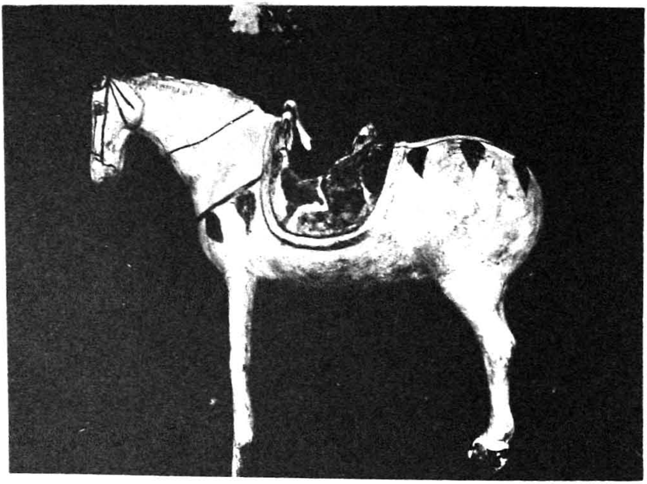

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FIG. 46.

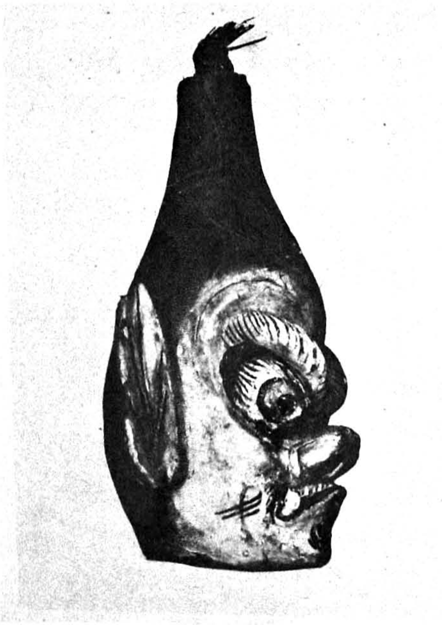


FIG. 47.

FIG. 48.

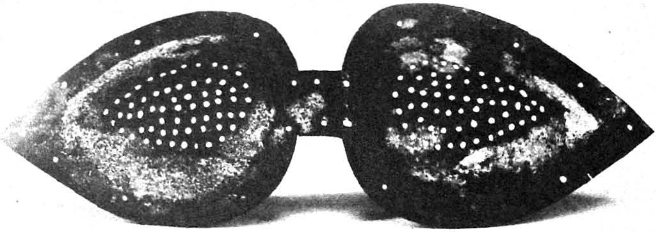
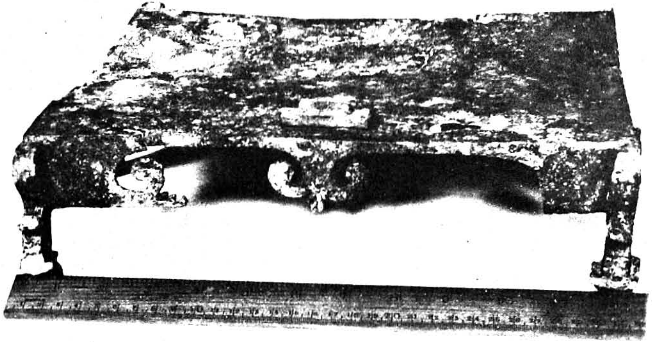


FIG. 49.

FIG. 50.

FIG. 51.

FIG. 52.



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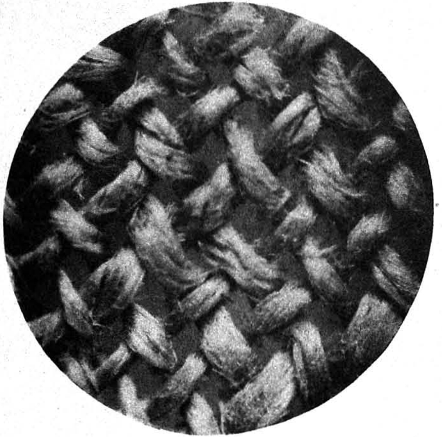

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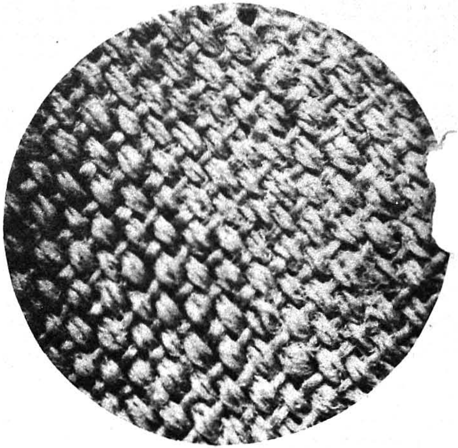

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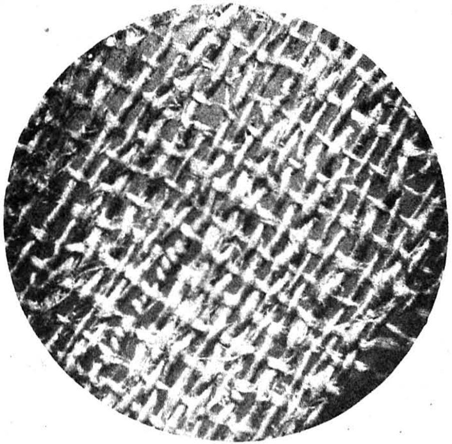

FIG. 57.

FIG. 58.

FIG. 58A.

FIG. 59.

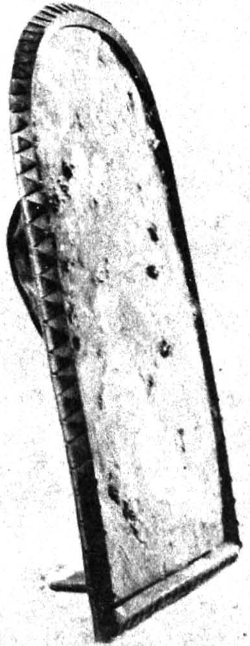

FIG. 59B.

FIG. 59A.

FIG. 60.

FIG. 60A.